AD-A090 781 SRI INTERNATIONAL MENLO PARK CA F/G 1/2
AIRPORT AND AIRSPACE DELAY MODEL DESCRIPTION.(U)
OCT 79 J C BOBICK, G J COULURIS DOT-FA77WA-4033
UNCLASSIFIED FAA-AVP-79-11 NL

1 OF 2
AD A
090781

1

AD A090781

LEVEL II

DDC FILE COPY

DTIC
ELECTE
OCT 2 3 1980
S D
F

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

80 10 21 11?

Report No. FAA-AVP-79-11

AIRPORT AND AIRSPACE DELAY MODEL DESCRIPTION

J. C. Bobick
G. J. Couluris

SRI INTERNATIONAL
Menlo Park, California 94025

October 1979

Final Report

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
OFFICE OF AVIATION POLICY
WASHINGTON, D.C. 20591

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FAA-AVP-79-11	2. Government Accession No. AD-A090781	3. Recipient's Catalog No.
4. Title and Subtitle Airport and Airspace Delay Model Description		5. Report Date October 1979
		6. Performing Organization Code Transportation Center
7. Author(s) J. C. Bobick, G. J. Couluris		8. Performing Organization Report No. SRI Project 6824
9. Performing Organization Name and Address SRI International 333 Ravenswood Avenue Menlo Park, California 94025		10. Work Unit No.
		11. Contract or Grant No. DOT-FA77WA-4033
12. Sponsoring Agency Name and Address Department of Transportation Federal Aviation Administration Office of Aviation Policy Washington, D. C. 20591		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code AVP
15. Supplementary Notes		

16. Abstract

The Airport and Airspace Delay Model (AADM) is a computerized event-step simulation developed ~~by SRI~~ to replicate the movement of aircraft through enroute and terminal airspace and runway complexes. The model, which is written in the high-level SIMSCRIPT II.5 programming language, produces output statistics describing aircraft delay and travel time and a log of all simulation events.

AADM is designed to model various air traffic conditions including multiple airports, variable route structures and runway use configurations, variable separation rules and control procedures, multiple control sectors, sector capacities, wind conditions, aircraft performance characteristics, variable traffic loadings, and the like. The AADM program logic includes airspace traffic control and airport/airspace interface components. The airspace logic simulates three levels of the operational control process: Level I--tactical control; Level II--sequencing control; and Level III--strategic control. The airport/airspace interface logic simulates final approach, takeoff and landing interleaving and departure control procedures. The multiple airport complex and airspace serving the San Francisco area are used to demonstrate the AADM application.

17. Key Words Air traffic control, airport, airspace, delay, model	18. Distribution Statement

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 102	22. Price

Form DOT F 1700.7 (8-69)

CONTENTS

CONTENTS (Continued)

ILLUSTRATIONS

TABLES

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance and cooperation of the FAA in completing this research effort. The comments and suggestions of Mr. Walter E. Faison and Mr. Kenneth Geisinger of the FAA Office of Aviation Policy, who served as technical officers for this project, were valuable in contributing to the completion of this effort.

This research was conducted within the Transportation and Industrial Systems Center of SRI International. Dr. George Couluris served as project leader, and Mr. Joel Norman served as project supervisor. Project team members included Drs. John Bobick and Michael Tashker, who participated in the overall model design and programming. Dr. Bobick worked primarily on the design and programming of the control logic portions of the program. Dr. Tashker focused on the program framework and input and output routines. Mr. Donato D'Esopo of SRI provided expert consulting on the SIMSCRIPT II.5 programming language structure.

EXECUTIVE SUMMARY

The Airport and Airspace Delay Model (AADM), newly developed by SRI International for the Federal Aviation Administration, is an event-step simulation written in the high-level SIMSCRIPT II.5 programming language that traces the movement of individual aircraft through a link and node route network. AADM is designed to simulate the real-world processes by which aircraft fly through air-traffic-controlled enroute and terminal airspace and arrive and depart through airport runway complexes. AADM is capable of modeling:

- Airspace route structures and runway configurations
- Airspace and airport separation and related operating procedures
- Multiple airports
- Multiple control sectors
- VFR vs IFR procedures and visibility conditions
- Terminal routing plan changes
- Route restrictions
- Sector capacities
- Wind conditions
- Aircraft characteristics (e.g., type and speed).

The AADM modeling outputs include delay and travel time statistics and a log of all simulation events.

The AADM program includes two basic components:

- Airspace traffic control logic
- Airport/airspace interface logic.

The airspace traffic control logic simulates three levels of the ATC operational process: Level I--tactical control; Level II--sequencing control; Level III--strategic control. The Level I logic simulates the processes by which controllers maintain minute-by-minute separation between aircraft pairs by vectoring and path stretching, speeding up or slowing down, or holding aircraft. The Level II logic simulates the processes by which

controllers coordinate their near-term separation service plans and sequence and space aircraft for downstream merges. The Level III logic simulates the processes by which controllers coordinate their multisector procedural rules (e.g., in-trail spacing adjustments at facility boundaries) and meter aircraft into, out of, and through the airspace network to balance traffic flows.

The airport/airspace interface logic simulates three runway-system-dependent components of ATC operations: final approach control, takeoff/landing control, and departure control. The final approach logic simulates the fine tuning of separations (largely by speed control) along the approach courses to runways and allows for VFR pairwise side-by operations and IFR in-trail separation requirements. The takeoff/landing logic simulates the specific separation procedures for a selected runway system that allow interleaving of crossing, same-direction, or parallel arrival and departure operations. The departure logic simulates the control procedures by which successive departures take off from identical, crossing, or parallel runways (provided that landing operations do not interfere) by taking into account runway occupancy times, runway exit and intersection locations, airspace spacing requirements, and special route restrictions.

The Oakland Bay TRACON's airspace was used to demonstrate an application of AADM. This airspace has a rather complex route structure mainly serving airports at San Francisco, Oakland, and San Jose. AADM simulated the major elements of this airspace and the three-airport operation using routing, traffic loading, and control procedures data collected from the local ATC facilities.

I INTRODUCTION

The Airport/Airspace Delay Model (AADM) is an event step computer simulation program that quantitatively estimates aircraft travel time and delay. The model, which is written in the SIMSCRIPT II.5 programming language, can be used to simulate both enroute airspace and terminal airspace with multiple airports. AADM replicates airspace route structures and runway configurations (exclusive of taxiways and aprons) and models such operational elements as separation procedures, air traffic flight patterns and traffic loadings, runway occupancy, aircraft overtakes, path crossing, holding at navigational fixes, airspace sectorization, sector workload constraints, and aircraft delays due to speed changes, holding, and vectoring. The program can simulate changes to wind, visibility conditions, and runway and airspace routine plans so that the user may examine particular situations and assess delay implications.

The simulation tracks individual aircraft on predefined routes. During the course of a simulation an aircraft moves along a series of airspace links from node to node. All aircraft are injected into the modeled airspace system at either an airport runway or a boundary node. Similarly, each route terminates at an airport runway or a boundary node. Thus, the user may simulate aircraft arriving in the terminal enroute airspace and landing at an airport, aircraft taking off from an airport and departing the airspace, aircraft taking off from an airport and landing at another airport in the modeled airspace, and aircraft transiting the airspace. An airport runway configuration (including exits and crossings) is modeled in sufficient detail to simulate arrivals, runway occupancy time, and sequencing of departures and arrivals. The rates at which

aircraft enter each route of the airport and airspace system are determined by user specified program parameters which enable traffic demand to change with time.

In order to facilitate simulation of two distinct air traffic operational environments--the airspace and airport systems--the AADM program includes two interrelated components:

- Airspace traffic control logic
- Airport/airspace interface logic.

This software structure enables separate development and refinement of the programming logic appropriate to each component and allows for the establishment of logic linkages between the two; other programming components conduct data input, output, and model supervision processes. The airspace traffic control logic simulates the control processes by which controllers maintain pairwise aircraft separations, sequence and space aircraft for downstream merging, and regulate areawide traffic flows. The airport/airspace interface logic simulates the processes by which aircraft transition between the airspace and airport runway environments and move through runway systems.

The AADM is structured to allow modular operation of the two components, should the need arise. This capability enables modeling of airspace regions which do not interface with airports as well as the modeling of runway systems and their final approach and departure airspaces. An overview of the modeling features of the two logic components is given in the remainder of this section.

A. Airspace Traffic Control Logic Overview

AADM simulates the movement of aircraft through an airspace system by modeling each aircraft's flight path and speed preferences and by

modeling the various air traffic control (ATC) actions used to expedite traffic flow and maintain aircraft separations. These control actions range from the detailed monitoring and adjustment of individual aircraft trajectories to the setting of overall procedural constraints and guidelines for the use of the airspace and airport runway systems. In order to realistically simulate the intrinsically complex nature of ATC operations, the airspace traffic control logic is structured according to a multilevel interactive hierarchical decomposition concept consisting of:

- Level I--Tactical Control
- Level II--Sequencing Control
- Level III--Strategic Control.

This three-level programming framework is used to represent as closely as possible the actual control procedures observed and studied by SRI, and is applicable to both enroute and terminal operations.

1. Level I--Tactical Control

At the tactical Level I, the AADM program provides a detailed, event-step, aircraft-following simulation of the movement of aircraft through the airspace route structure. As individual aircraft are tracked through the route network, specific events (e.g., crossing and merging conflicts) are generated which require control actions to ensure that safe separation and operating standards are met. The control actions, which include vectoring and path stretching, speeding up or slowing down, or holding maneuvers to resolve situations, are modeled by Level I. The Level I logic is used to model such situations as those that entail conflict resolutions, sector workload constraints, and terminal traffic plan changes.

Conflict Resolution--The Level I conflict resolution process can be explained with the aid of Figure 1, which shows a subset of the links and

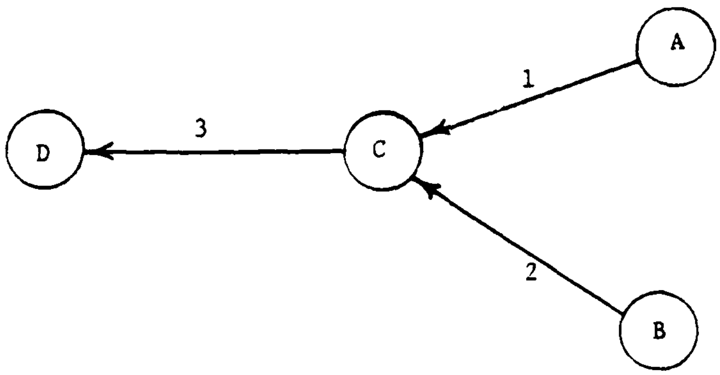

FIGURE 1. LEVEL I TACTICAL CONTROL

nodes used to represent an airspace network. Each link represents a unique flight path joining two points in three dimensional space, with each such point represented by a node. The Level I software moves aircraft from one node to the next along a directed link and adjusts the motion of aircraft to guarantee proper separation at each node and thereby resolve potential crossing, merging, or overtaking conflict. In Figure 1, aircraft on links 1 and 2 are adjusted (by speed or vectoring control) or held at nodes A or B to prevent merging conflicts at the downstream node C. In parallel with the tracking of aircraft approach node C, the Level I logic will monitor aircraft along link 3 to ensure proper separation at node D.

Subroutines within Level I enable a variety of control actions consistent with the specification of the airspace operation being modeled. Such specifications, which are defined during data input, describe the types of operations that are permitted along each link (e.g., whether or not overtaking is allowed, or whether speed or vectoring control is preferred), the operating environment (e.g., link heading, distance, wind vector, aircraft capacity, and visibility conditions, as well as node altitude, aircraft holding capacity, and separation rules in effect), and aircraft characteristics (e.g., aircraft type, planned flight speed, range of permissible speed change, and planned route profile). The Level I logic selects the intervention tactics representative of the actions taken by controllers as they continually monitor aircraft on a minute-by-minute basis and tabulates travel time and delay (positive or negative) data.

<u>Sector Workload Constraints</u>--The Level I logic tracks the movement of aircraft through each ATC sector to check for and prevent traffic loading situations that would violate sector workload constraints. Each sector is identified in AADM by a unique set of links that make up its airspace.

The AADM user may specify a workload constraint represented by a maximum number of aircraft for each sector. If an aircraft attempts to enter a link in a workload saturated sector, the program will hold that aircraft at its current node until the downstream sector becomes unsaturated and will update the travel time and delay tabulations.

Terminal Traffic Plan Changes--Terminal airspace approach and departure routings depend in part on airport locations, local terrain, runway configuration, and meteorological situations. Changes to these situations--especially wind speed and direction and runway closures--trigger revisions to the terminal traffic plan in effect. Typically, a significant change in wind will cause a plan "turnaround" in which new approach and departure routings are implemented with allowances for transitioning from the old to the new plan. The AADM simulates such plan changes at any point during a model run and employs portions of the Level I logic to carry out the transition from one plan to another. This logic ensures that proper separations are maintained when aircraft alter their routings. The AADM plan change logic, which involves Levels II and III as well as Level I, enables simulation of transitions between IFR and VFR operations.

2. Level II--Sequencing Control

The Level II logic models the processes by which controllers "look-ahead" along the route structure network and coordinate the movement of individual aircraft in anticipation of specific downstream operational requirements. Such actions are aimed at expediting the movement of traffic and preventing congestion problems from developing which cannot be reasonably handled at the tactical level. The primary use of the Level II logic is to simulate the sequencing and spacing of aircraft for downstream merges.

Figure 2 shows a link and node representation of a hypothetical route network serving approach traffic to two airports. The approach fix for one airport is at node X and aircraft approaching this airport enter the route system at boundary nodes A, B, C, D, E and F. The Level II logic "sets-up" all aircraft destined to merge at the approach fix node X by initiating sequencing and spacing control actions when the aircraft enter the route system at the boundary nodes. For example, an aircraft on link 1 and one on link 3 (which could be in two different sectors) would be maneuvered by the Level II logic so that they would be properly spaced for sequencing on to the final approach course at node X. The spacing adjustments would be in conformance with the separation rules in effect at node X, would involve vectoring and path stretching, speed control or holding actions, and would be performed repeatedly as aircraft move from link to link toward the approach fix.

The sequencing logic is carried out within the constraints permitted by the Level I tactical control logic which is operating in parallel to Level II. For example, Level I will ensure that proper spacing is effected at node G for each aircraft on links 1 and 2, while Level II will sequence these aircraft with each other and with all other aircraft on links of routes merging at the approach fix node X. The AADM program will update the aircraft travel time and delay tabulations in accordance with the simulated control actions.

The Level II logic is designed to coordinate aircraft movement in a multiple-airport environment by sequencing aircraft to selected merge points. As shown in Figure 2, aircraft passing through boundary nodes may be sequenced to either approach fix node X or node Y depending on which of the

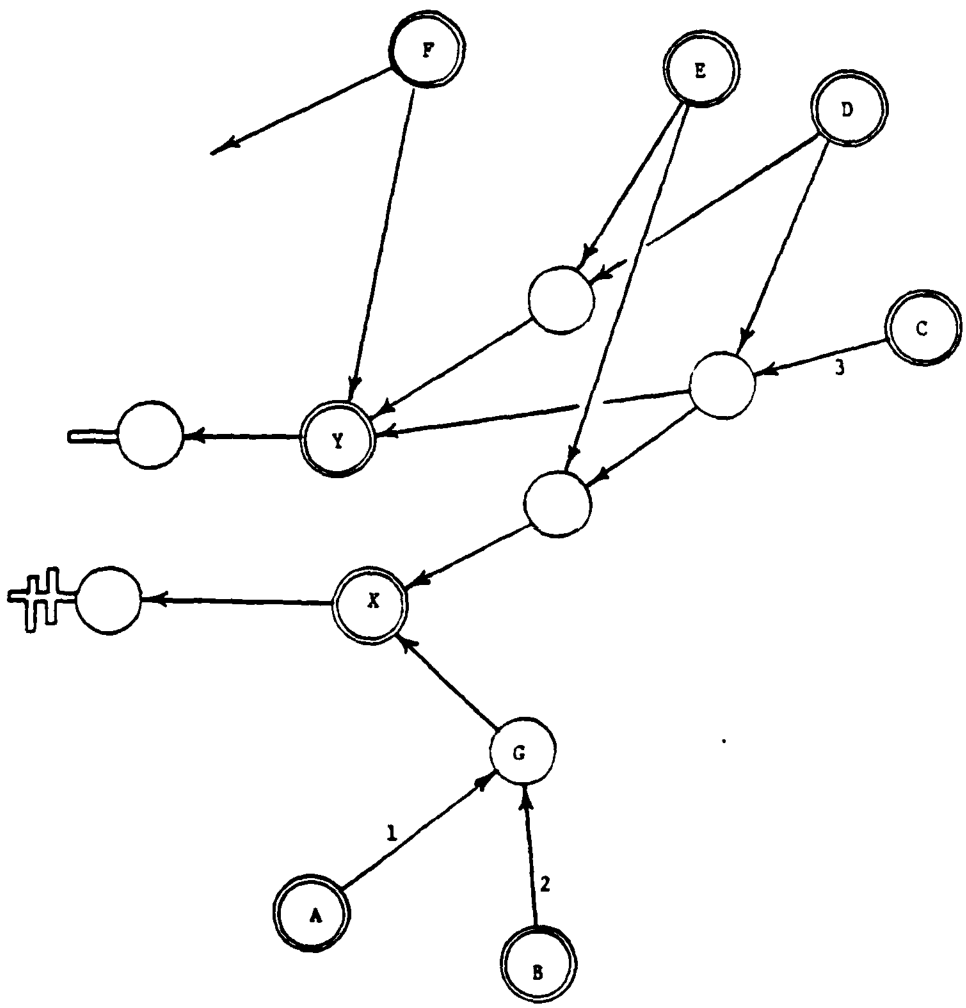

FIGURE 2. LEVEL II SEQUENCING CONTROL

two airports are the destination. However, the Level II logic is not constrained to simulating only airport merging operations; any airspace merging situation can be simulated by designating an appropriate Level II merge or "post" node and corresponding Level II "feeding" or "metering" nodes. Also, Level II post and metering nodes must be specifically defined for each terminal traffic plan under study so as to distinguish the sequencing procedures appropriate to each plan.

3. <u>Level III--Strategic Control</u>

The Level III logic simulates the processes by which controllers coordinate and implement systemwide procedural rules and regulate or meter traffic through their airspace. Such actions balance traffic flows through the overall route network by setting flow constraints compatible with downstream acceptance rates. The primary use of Level III is to determine separation rules for key network control points--especially facility boundaries--so that traffic is fed at realistic rates into the tactical and sequencing control environment. In effect, the Level III strategic control logic serves as a traffic modulator which ensures that aircraft concentrations do not occur that would overpower the capabilities of the Level I and II operations to move traffic.

The link and node network shown in Figure 2 is shown again in Figure 3, but with a hypothetical TRACON facility boundary designated through nodes A, B, C, D, E, and F. For the purpose of the Level III logic, nodes X and Y are designated as post nodes for traffic entering the final approaches on links from the Level III boundary nodes. The Level III logic meters traffic through each boundary node by specifying in-trial spacing rules (e.g., 5, 10, or 15 nautical miles) that are compatible with the separation

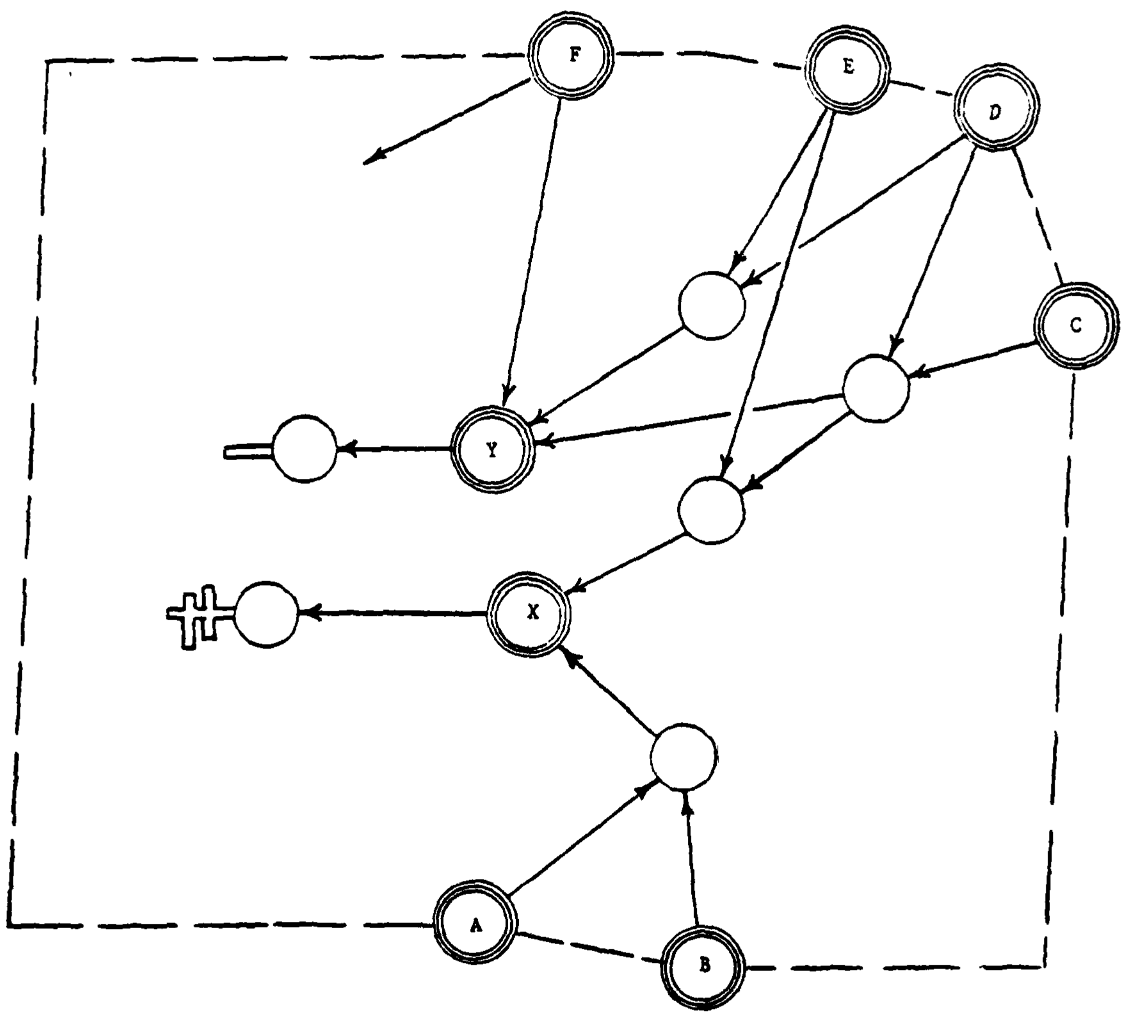

FIGURE 3. LEVEL III STRATEGIC CONTROL

and traffic loading requirements of post nodes X and Y. This process balances the flow rate through each boundary node to match the acceptance rate of the final approach post nodes and is based in part on the projection of pending arrivals during successive user-specified time intervals (e.g., 1, 2, 5, or 10 minutes).

The Level III logic responds to time-changing variances in traffic loadings along each route. In Figure 3, a heavy traffic loading is indicated along the route through node C to post node X and less intense traffic loadings are indicated on the other inbound routes. Level III will calculate the in-trail spacing rules for each boundary node for an upcoming time interval so as to expedite flow along the heavily loaded route. This process is dynamically self-adjusting in that the Level III logic will recalculate spacing requirements for successive time intervals during the course of the simulation and thereby react to changing traffic demand circumstances.

The Level III post and metering nodes need not be identical to the Level II post and metering nodes, but as in the case of the Level II operation, all post and metering nodes applicable to different terminal traffic plans must be specifically defined for each plan.

B. Airport/Airspace Interface Logic Overview

The AADM program enables modeling of traffic operations for each of the airport runway systems under study and provides for interfacing each such runway system model with its counterpart model of airspace traffic control. The airport/airspace interface software simulates the control actions placed on aircraft while executing approach and departure operations

through the runway system and adjacent airspace, and consists of three subcomponents that model travel time and delay impacts associated with:

- Final approach control
- Takeoff/landing control
- Departure control.

The three subcomponents are interactively linked to ensure that all aspects of airport-related traffic movement are properly integrated in the AADM program. The airport/airspace interface logic may be used to simultaneously model any number of airports using input data that separately describe each airport. Such data as runway occupancy times, separation rules, and runway utilization procedural descriptions must be defined for each airport as appropriate for each terminal traffic plan under study.

1. Final Approach Control

The final approach control logic simulates the processes by which controllers setup, monitor, and fine-tune the spacing of aircraft along the final approaches to a runway system. This logic is applicable to single runway operations or more complex ones such as the closely-spaced parallel runway pair shown in Figure 4. Nodes 1 and 2 represent the runway landing thresholds and nodes 3 and 4 represent the fix at which aircraft initiate final approach to their respective runways.

Under VFR operating rules, pairwise operations are permitted in which two aircraft may approach in a side-by configuration so long as suitable separation is maintained between preceding and following aircraft. Such side-by operations are useful in busy runway situations where crossing departures are interleaved between suitably spaced arrival pairs. Controllers setup the VFR operation by coordinating the turning of aircraft through approach

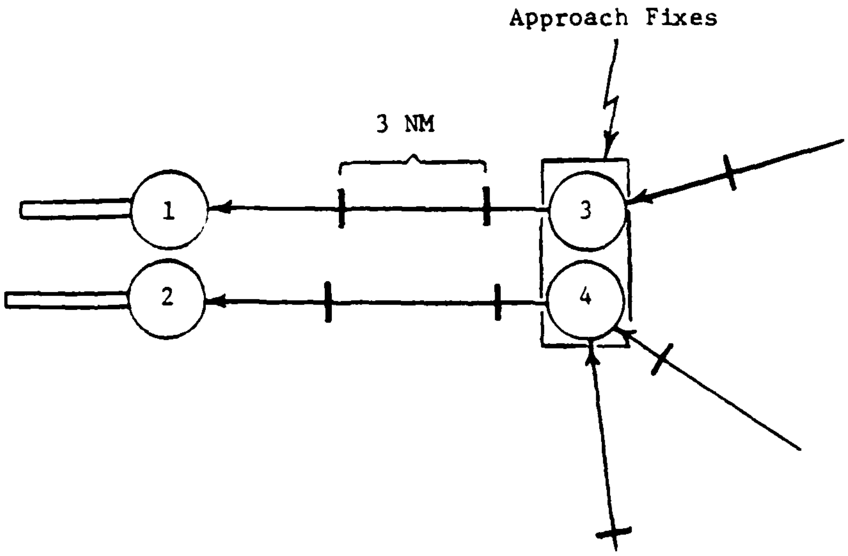

FIGURE 4. FINAL APPROACH CONTROL--VFR

fix so that side-by or near-side-by situations exist. Controllers then monitor the final approach and endeavor to maintain the side-by configuration and spacing (usually by speed control instructions) although pilots have considerable influence over the actual flight pattern flown under visual conditions.

The AADM final approach logic is designed to model the above described VFR operation where such procedures are in effect. Program algorithms--which are actually imbedded in the Level I airspace traffic control logic, but can be operated independently of the airspace model--simulate the setting-up maneuvers (e.g., speed control, vectoring) required for pairwise coupling as the aircraft converge on the approach fixes, and simulate their movement along final approach. The program enables the modeling of variations from the strict side-by configuration by permitting aircraft in a couple to deviate logitudinally from their intended position (e.g., one aircraft in a side-by pair may be allowed to position itself some distance--such as one mile--ahead of or behind the other aircraft). The final approach logic also ensures that landing runway operating rules are not violated by checking data describing runway occupancy times for specific aircraft types and exit distances.

The corresponding IFR operation, as illustrated in Figure 5 for the closely-spaced parallels, does not permit simultaneous side-by approaches. The final approach logic handles this situation by ensuring proper separation (e.g., 3 nautical miles or more for wake turbulence) between each successive aircraft regardless of approach course and simulates the setting-up of IFR spacing as aircraft converge on the approach fixes.

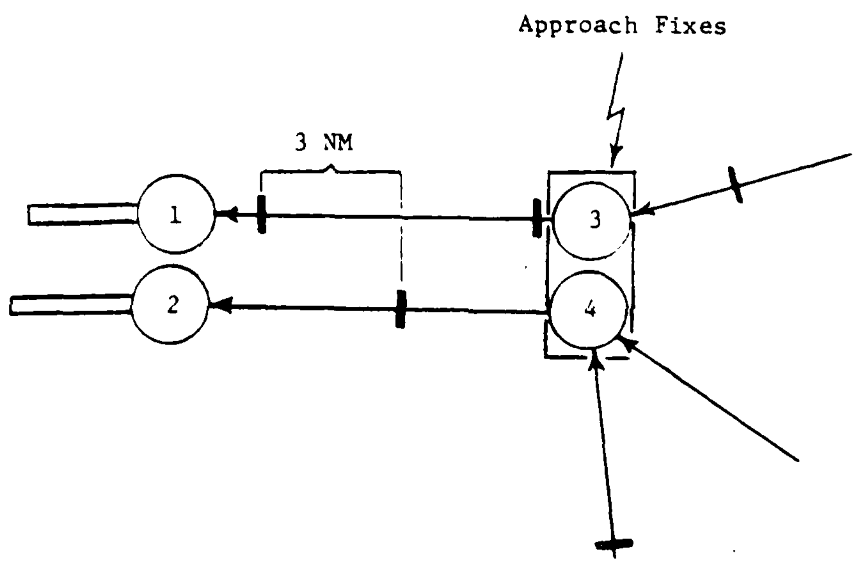

FIGURE 5. FINAL APPROACH CONTROL--IFR

2. Takeoff/Landing Control

In many operating situations, the geometry of the runway configuration requires that a high degree of coordination be effected between takeoff and landing maneuvers to maximize runway utilization. Typically, takeoffs and landings are interleaved with each other subject to the constraints of the separations required for arrival aircraft. The AADM takeoff/landing control logic simulates the process by which departing aircraft are interleaved between arrivals.

Figure 6 shows a runway configuration consisting of two pairs of crossing parallels. An aircraft waiting at a departure runway threshold will not be cleared for takeoff if its runway is "blocked" by an arriving aircraft using a crossing runway. In the Figure 6 example, such blockage occurs when a landing aircraft is between a check point 2 nautical miles from the arrival runway threshold and the intersection of the arrival and departure runways; the blockage ends when the intersection is cleared. The takeoff/landing logic checks the location of landing aircraft (for both arrival runways) to determine whether a pending departure needs to be delayed until suitable separation situations occur. The takeoff/landing control logic of AADM may be applied to any runway configuration.

3. Departure Control

In addition to satisfying separation rules associated with arrival interactions, departure operations must also conform to separations requirements for successive departures. The AADM departure control logic performs the final check required before an aircraft takeoff operation can be initiated in the simulation.

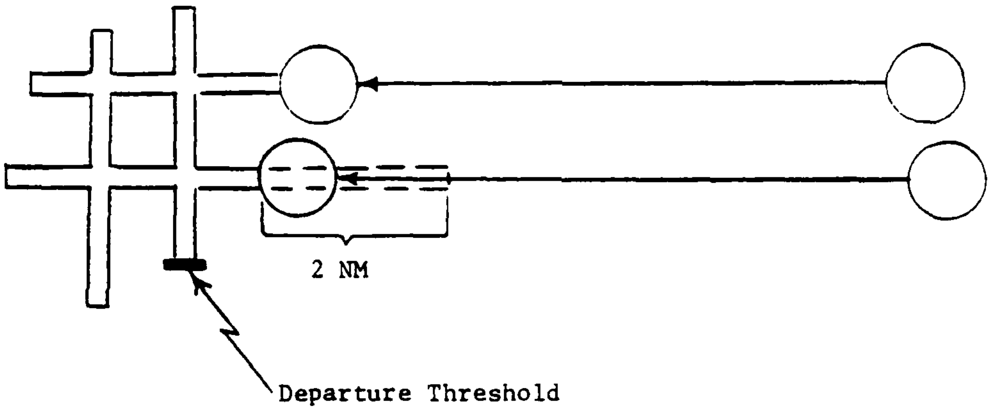

FIGURE 6. TAKEOFF/LANDING CONTROL

Figure 7 demonstrates the types of control complexities involved for a pair of closely-spaced parallel departure runways. In this case, the issuance of departure release is subject to the satisfaction of various criteria describing runway occupancy and airspace spacing constraints. The spacing rules vary according to whether successive aircraft are diverging or following each other, whether at least one aircraft is heavy, which runways are being used, whether the aircraft are on common departure routings, and whether special procedures are in effect (e.g., San Francisco to Los Angeles departures restricted to 10 nautical mile spacing). The departure control logic of AADM may be applied to all selected runway configurations.

C. AADM Refinements

The AADM was developed by SRI using the airspace and multiple airport system of the FAA's Oakland Bay TRACON as a test model and reference point to guide the design and structuring of the program. Thes test bed was of suitable complexity to enable development of the software structure to the level of sophistication needed to depict real-world operations. However, further experimentation is required to check out some of the more intricate details of the model and to refine its operation to ensure confidence in its general use. The current level of model development is at a stage that would permit refinements to be made in conjunction with a model validation effort. Refinements envisioned include model adjustments that would further generalize the logic, increase the processing efficiency of the program code, increase ease of use, provide additional output options, or expand modeling capabilities (e.g., additional control strategy, real time workload assessment, communication loading analysis, or fuel consumption estimation routines).

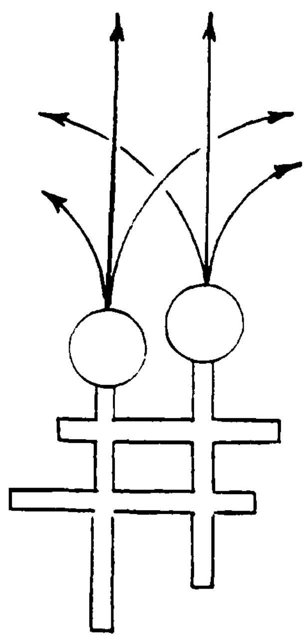

FIGURE 7. DEPARTURE CONTROL

II AADM STRUCTURE

The structural design of AADM is greatly influenced by the structure of the SIMSCRIPT II.5 computer language in which it is coded. Within the language are structural elements called entities. A model entity may correspond to a real-world object or process, or it may be a modeling artifact to facilitate the coding of logic. An entity may have attributes. These attributes describe the entity. An attribute may be a physical characteristic or parameter, a descriptor of the state of the entity, or information pertaining to the internal logic of the model.

Another structural element within the SIMSCRIPT language is called an event. Events are time-dependent occurrences that control the flow of logic within the simulation. These events may be external or internal in nature. External events are those which are directly controlled by the user of a model via input data. Internal events are those generated within the model as a result of the programmed logic. The SIMSCRIPT timing routine and event processor automatically keeps track of pending events, advances the simulation clock, and executes the event that is due to occur next. The execution of an event involves the exercise of some model logic. This may include exercising model routines, updating the values of the attributes of entities, scheduling additional events, cancelling pending events, etc.

In the remainder of this section, the entities, attributes, and events of AADM are described. This information is useful because it demonstrates how physical objects, processes, and parameters are represented in the AADM

simulation. It is also indicative of the level of detail at which the logic operates, the sensitivity of the model to various parameters, the control and flow of logic, and the real-world events which the model is designed to handle.

A. Simulation Entities

The major simulation entities of AADM include:

- Nodes
- Links
- Routes
- Sectors
- Aircraft
- Airports.

Brief descriptions of these entities and some of their associated attributes (i.e., descriptive parameters) follow.

1. Nodes

A node represents a point in three-dimensional space. It may correspond to a navigational fix (VOR, marker, or intersection), an airport, a point along a route at which an altitude or direction change is required, or a point at which an aircraft may enter the modeled airspace. A node may be joined to as many other nodes as required, each by a single link. A node is further defined in terms of a set of attributes. Attributes which are specified by user input include the altitude of the node, the strategy to be used to place aircraft on links approaching the node, the maximum number of aircraft that may be held at the node, and the type of logic to be used to determine if an aircraft can enter a link approaching the node if there are aircraft being held at the node. The user also specifies a minimum separation distance for aircraft approaching the node that is due to sequencing or flow control. This spacing may be changed by

the AADM logic which periodically adjusts strategic spacing constraints based on traffic and airport conditions.

A node also has several parameters which designate additional properties that a node might possess. These parameters are used to identify a node as an airport/airspace interface node, a critical bottleneck in the system where look-ahead control logic is desired, or a point where flow control logic is to be employed. In addition, several attributes are maintained to describe the current state at a node for use in the model logic.

2. Links

A link is a path between two nodes with a given length in nautical miles and magnetic heading in degrees. A link may be a curved path; however, in such cases, the mean link heading will be used to approximate the effect of wind on aircraft traveling on the link. A link carries single directional traffic only and is therefore defined in terms of a from-node and a to-node. A link can belong to a specific windset; this is a group of links for which direction and speed of the wind in the surrounding airspace are the same. A link may also belong to a specific sector; this is discussed in the sector section. A mate may also be designated for a link. Attempts are made to control aircraft in pairs along mated links. This simulates such procedures as final approach to closely-spaced parallel runways under VFR conditions.

A link is further defined in terms of five other parameters: the maximum number of aircraft allowed on the link, the maximum time any aircraft may be vectored on the link, the link type, the overtake flag, and the ordering flag. The link type refers to a particular set of

maximum, nominal, and minimum speeds for each aircraft type when traveling on the link. The overtake flag indicates whether an aircraft entering a link is allowed to overtake slower aircraft already on the link. The ordering flag indicates whether attempts are to be made to avoid having light aircraft trailing heavy aircraft.

3. Routes

A route is an ordered set of nodes that an aircraft will encounter between its origin node and its destination node. Either the first node, the last node, or both may be defined as airports. The exact sequence of nodes followed by an aircraft transiting the airspace is not fixed. It is dependent upon the airport/airspace traffic routing plan in effect when the aircraft enters the airspace and is sensitive to any changes in the traffic plan while the aircraft is transiting the airspace. Route definition allows the specification of aircraft rerouting and the transition between traffic plans for aircraft in the modeled airspace.

4. Sectors

The sector entity in AADM allows sectorization of the airspace to be represented. Each sector consists of a group of links that make up its airspace. Each sector may have a maximum workload or maximum number of aircraft associated with it. If an aircraft attempts to enter a link in a loaded sector,it will be held at its current node until the sector becomes unsaturated.

5. Aircraft

Each aircraft entity has associated with it the type, a route, a total delay incurred, and a number of parameters that describe current

position and progress in the system. Every aircraft type has a number, an alphanumeric name, minimum, nominal, and maximum speed for each link type, and a minimum ceiling and runway visual range allowable for landing. In addition, every pair of types has a minimum separation distance associated with it. The traffic loading of the airspace/airport system is controlled by the user through the events ARRIVAL, DEPARTURE, MULTARR, and MULTDEP. These events control the traffic distribution in terms of aircraft types, routes, and time distributions for airborne aircraft entering the airspace and aircraft requesting departure clearance at airports in the system. The time distribution of aircraft may be deterministic or stochastic.

3. Airports

Each airport has an alphanumeric identifier and is associated with one or more airport/airspace interface nodes. An airport has a current value of ceiling and runway visual range, both of which may be changed with a weather event. The ceiling and runway visual range of the airport is used in conjunction with the minimum ceiling and minimum runway range of a particular category of aircraft to determine whether an aircraft can land or must execute a missed approach.

For each airport/airspace interface node, a set of allowable departure and arrival procedures is defined for each airport/airspace plan. Each procedure is defined in terms of constraints on other procedures due to runway occupancy times and airspace separation requirements. The level of detail of representation of airport operating procedures is controlled by the definition of procedures, which allows an airport to be represented simply by a node with an entry/exit rate constraint or by

a complex multirunway operating plan with complex interactions between departures and arrivals. Departure route separation restrictions and interrelationships between operations at different airports in the modeled system may be treated.

B. Simulation Events

External events allow the user to control the flow of logic via input data. At any time during the simulation the user can designate an external event to occur. The external events of AADM include:

- Arrival
- Multarr
- Departure
- Multdep
- Wind
- Weather
- Plan
- Trace.

A general description of these events follows. There are also internal events which are scheduled by the internal simulation logic. These are more closely associated with the simulation logic and are described in a later section of this report.

1. Arrival

The arrival event provides the user with the capability to specify that an aircraft of a given type will arrive in the modeled airspace on a specific route at a specific time. Thus, a user could specify a deterministic aircraft arrival schedule using this event.

2. Multarr

The multarr event provides the user with the capability to specify a stochastic time distribution of aircraft arrivals. Parameters of this event include type of aircraft, the arrival route, the number of aircraft

to arrive, the statistical time distribution of arrivals, and the time interval over which the arrivals are to be distributed.

3. Departure

This event is analogous to the arrival event with the exeeption that it is concerned with prescribing of aircraft departure requests at airports.

4. Multdep

The multdep event is analogous to the multarr event for airport departures.

5. Wind

The wind event provides the user with the capability to change wind conditions at any time during the simulation. The wind condition may be changed separately for each set of links in a windset. The parameters in this event are the windset number for which wind conditions are changing and the new values of the wind direction and speed.

6. Weather

The weather event enables the user to modify the visibility conditions at an airport in the system at any time during the simulation. The parameters include the airport at which conditions are changing, the new values of the ceiling, and the runway visual range at the designated airport.

7. Plan

The plan event provides the user with the capability to trigger a traffic plan change at any time during the simulation. The parameters of this event include the new plan number, a flag to specify whether or not all departures under the new plan are to be held until arrivals under the old plan which are too close to the airport to be rerouted have landed, and the minimum time period during which departures

are to be held (e.g., to simulate taxiing to a new departure runway). This event triggers rerouting of aircraft, resetting of strategic traffic flow constraints, etc., to simulate a plan change.

8. Trace

One form of output of AADM is a detailed accounting of the progress of each aircraft through the system. The trace event provides the user with flexibility to turn this output on and off at will during the simulation. This permits the user to obtain detailed simulation log output only during those periods of the simulation when such output may be of special interest (e.g., for a period of time after a plan change).

III AADM PROGRAM LOGIC

A. Definition of Routines

The SIMSCRIPT II.5 program for AADM comprises over 60 routines. A list of these routines, together with brief descriptions of the routines, follows:

AIRPORT.INPUT--This routine is called by MAIN to read and process user input for the keyword "AIRPORT." This includes definition of each airport in the system in terms of associated airport/airspace interface nodes and departure and arrival procedures to be used under each plan for each of these nodes.

ARRIVAL--This event routine is called when an arrival event occurs. It creates the arriving aircraft entity and initializes its attributes. Control logic is then called upon to determine the aircraft movement.

CONTROL--This routine is the key driver routine in determining aircraft movements at Levels I and II. It calls upon routines which contain the various alternative control strategies.

DEPARTURE--This event routine is executed whenever a departure event occurs. It creates a departure request, records data about this request, and places the request on the departure queue at the appropriate airport.

EARLY·TOA--This routine, which supports several control logic routines, is used to determine the earliest time-of-arrival of an aircraft at the next node along its route.

EJECT--This routine is called when an aircraft has left the system, having either transited the airspace or landed at an airport. Relevant statistics are updated and the aircraft entity is destroyed.

END.REP--This routine prints a final report of the simulation results and then stops the simulation.

END.SEED--This event routine is called at the end of the simulation seed time. Various counters are reinitialized and a report of results is printed.

END.SIM--This event routine is called at the time the simulation is terminated. It calls routine END.REP to have a final report printed.

ENDDELAY--This event routine is executed when an aircraft is expected to be able to leave a holding queue and proceed along its route.

FIX.AIR.TIMES--This routine is called when the aircraft arrives at the airport/airspace interface node upon departure; it sets minimum times for subsequent related procedures based upon airspace constraints. It also sets any relevant route restriction constraints. The routine is also called when an aircraft is on its final link into an airport to set logic which will prevent departure procedures from occurring when the arriving aircraft is too close to the airport.

FLOW.INPUT--This routine reads and processes input data associated with the keyword "FLOWS." These data specify the Level III control parameters.

FLOW.UPDATE--This event routine calls upon the logic which recomputes and resets the Level III separation distances. It also schedules the next periodic Level III update based on the user defined frequencies for these updates.

FORCEFIT*--This routine places an aircraft at a specified position in the arrival queue at a node. Conflicts are resolved by controlling the entering aircraft, its predecessor in the arrival queue, and as many succeeding aircraft as necessary.

HOLDCHECK--This routine determines if an aircraft must be held at its current node position because of the holding situation at its current node, the next node, or a link capacity constraint.

LANDING--This routine includes the logic for attempting a landing at an airport. Routines MISSED.APPROACH, EJECT, and NEXTDEPARTURE are called upon as appropriate.

LATE.TOA--This support routine computes the latest time-of-arrival of an aircraft at the next node along its route.

LINK.INPUT--This routine reads and processes input data for the keyword "LINKS."

LINK1, LINK2, LINK3--These routines are called when the keyword "GO" is encountered. The various types of input data are linked together, error checking is done, and data are loaded in the form required to initiate the simulation.

MAIN--This routine acts on the control program module during the data input phase. It reads input keywords and passes control to the appropriate input routines. It calls routines for linking the input data and printing the input data, then starts the simulation which passes control to the SIMSCRIPT TIMING ROUTINE.

*Not yet implemented.

METERCONTROL--This routine provides one strategy for Level II control logic. It looks ahead to designated "POST" nodes and checks for future conflicts. If a future conflict exists, control actions are taken to eliminate partially or fully the anticipated conflict.

METERING.INPUT--This routine is called to read and process input data for the Level II control strategy when the keyword "METERING" is encountered by MAIN.

MISSED.APPROACH*--This routine is called when an aircraft on final approach must execute a missed approach.

MOVECHECK--This event routine checks to determine whether a holding aircraft can be cleared to proceed along its route.

MULTARR--This event routine is exercised when the user specifies an external event MULTARR. The routine generates ARRIVAL events according to the user input specification.

MULTDEP--This event routine generates DEPARTURE events according to the user input data when an external event MULTDEP occurs.

MULTFIT--This event routine attempts to place the aircraft at a specified position in a node arrival queue by controlling the entering aircraft and the aircraft preceding and following it on the queue. Attempts to resolve conflicts include controlling the entering and preceding aircraft, then the entering and succeeding aircraft, and finally controlling all three aircraft.

---

*Not fully implemented.

NEXTDEPARTURE--This routine determines the next departure to occur at an airport and schedules a TAKEOFF event at the expected clear-to-roll time. This routine is called when anything occurs at an airport which may affect the next departure.

NODE.ARRIVAL--This event routine is exercised whenever an aircraft arrives at a node. It calls upon logic to land, eject, or move the aircraft toward its next node as appropriate.

NODE.DEPARTURE--This routine embodies the logic involved with releasing an aircraft from its current position at the link leading to the next node along its route. It calls upon routine CONTROL to determine necessary control actions.

NODE.INPUT--This routine reads and processes user input for the keyword "NODES." These data include definition of the nodes for the system being modeled.

NOMFIT--This routine places an aircraft in a node arrival queue at the position of order at which it "normally" would arrive without any control actions, if a conflict would not result. The nominal position is based on the arrival time of the aircraft at the node assuming it travels the link at the user input nominal speed for the link.

OKMOVE--This routine checks to determine whether an aircraft at a node must be held there based on the user-specified holding strategy at the node.

PAIRCONTROL--This routine embodies the logic for controlling aircraft in pairs along mated links (e.g., final approach links to closely spaced parallel runways under VFR conditions). This logic pairs aircraft as they approach the initial node of the mated links and takes control actions for pairs of aircraft on the mated links to simulate side-by flight.

PERIODIC.REP--This event routine is executed periodically to print a report of results for each time period of the simulation. It schedules the next PERIODIC.REP event.

PLAN--This event routine is executed when a user specified plan event occurs. It contains logic for resetting variables required for turning around the airport and airspace operations, including the transition between plans.

PLAN.INPUT--This routine is called by MAIN when the keyword "PLANS" is encountered. It reads and processes data which specify mappings of routes among the airport/airspace plans.

POSTING--This routine removes an aircraft from the list of aircraft that are approaching a given LEVEL II node when the aircraft has arrived there.

PREAMBLE--This SIMSCRIPT module defines the structure of the AADM simulation. It defines the entities, attributes, events, and variables and arrays which are common to all routines.

PRINT.INPUT--This routine is called by MAIN when the keyword "PRINT" is encountered. It provides the user with the capability to select the types of input data for which a printout is desired.

PRINT1, PRINT2--These routines provide a printed version of the various types of input data.

PROCBLOCK--This event routine implements the constraints that prevent departure procedures when an aircraft on final approach is too close to the airport.

PROCEDURE.INPUT--This routine is called by MAIN whenever the keyword "PROCEDURES" is encountered. It processes input data which specify the runway occupancy time and airspace distance constraints among airport arrivals and departures.

QFIFO--This routine contains control logic to place an aircraft last in a node arrival queue, initiating any control actions required to resolve conflicts. All control actions are imposed on the entering aircraft.

REPORTER--This routine is called upon by event routines END.SEED and PERIODIC.REP in printing simulation reports.

RESET--This routine supports several control routines. It contains the logic for resetting parameters and rescheduling events when a control action is taken on an aircraft or a link (instead of at a node).

ROUTE.INPUT--This routine is exercised when the keyword "ROUTES" is read by MAIN. It reads and processes data which define the route structure of the simulation.

SECTOR.INPUT--This routine is called by MAIN when the keyword "SECTORS" is encountered; it reads and processes data that define the airspace sectorization.

SETFLOWS--This routine periodically computes Level III flow constraints at the flowmeter nodes based on current and expected traffic loading and sets the strategic separation distances.

SPEEDFIT--This Level I control routine attempts to place the aircraft at a given position of order in a node arrival queue. Only control actions (e.g., speed changes, vectoring, holding) on the entering aircraft are considered.

TAKEOFF--This event routine contains the logic required to simulate an aircraft takeoff from an airport.

TIMING.INPUT--This routine is executed when the keyword "TIMING" is encountered in MAIN. It reads and processes data which set the simulation seed time, end time, and frequency of periodic reports of simulation results.

TOSH--This routine computes the minimum separation between two aircraft at a node. The separation depends upon minimum wake turbulence separations based on aircraft type as well as any strategic separation distances set at the node for controlling traffic flow.

TRACE--This event routine is exercised when a TRACE event is specified by the user. It provides for turning the detailed simulation log output on and off at will during the simulation.

TRACE.INPUT--This routine is called by MAIN when the keyword "TRACE" is encountered. It reads input data which specify the output desired in the simulation log.

TYPE.INPUT--This routine is called by MAIN upon encountering the keyword "AIRCRAFT." It reads and processes data that specify the speed range for each aircraft type for each type of link. The minimum separation distance between each pair of aircraft types is also specified.

UNSAT--This routine contains logic that releases aircraft from holding due to sector saturation whenever the sector becomes unsaturated.

WAKETURBULENCE--This routine is used when the user has specified that it is not desirable to have light aircraft behind heavy aircraft on a

given link. For a given position in a node arrival queue, this routine determines if placement of an arriving aircraft is desirable based upon waketurbulence separation requirements.

WEATHER--This event routine is exercised whenever a user specified WEATHER event occurs. It contains logic to modify the ceiling and runway visual range at an airport.

WIND--This event routine is exercised when a WIND event occurs. It contains logic for changing the wind direction and speed for the links in a given windset.

WIND.INPUT--This routine is called by MAIN when the keyword "WIND" is encountered. It reads and processes data defining the various windsets, i.e., groups of links that have the same wind conditions in the surrounding airspace.

These routines function within five major logical segments of the AADM program. These segments are

- Input lobic
- External event processing logic
- Simulation report logic
- Airspace traffic control logic
- Airport/airspace interface simulation logic.

Flowcharts demonstrating the interrelationships among routines functioning in each of the logical segments are presented in Figures 8 through 12. The coupling among the segments is depicted in this set of figures. Descriptions of each of the logical segments of AADM follow.

B. Input Logic

A flowchart of the AADM input logical segment is presented in Figure 8. At the beginning of a program operation, MAIN has control of

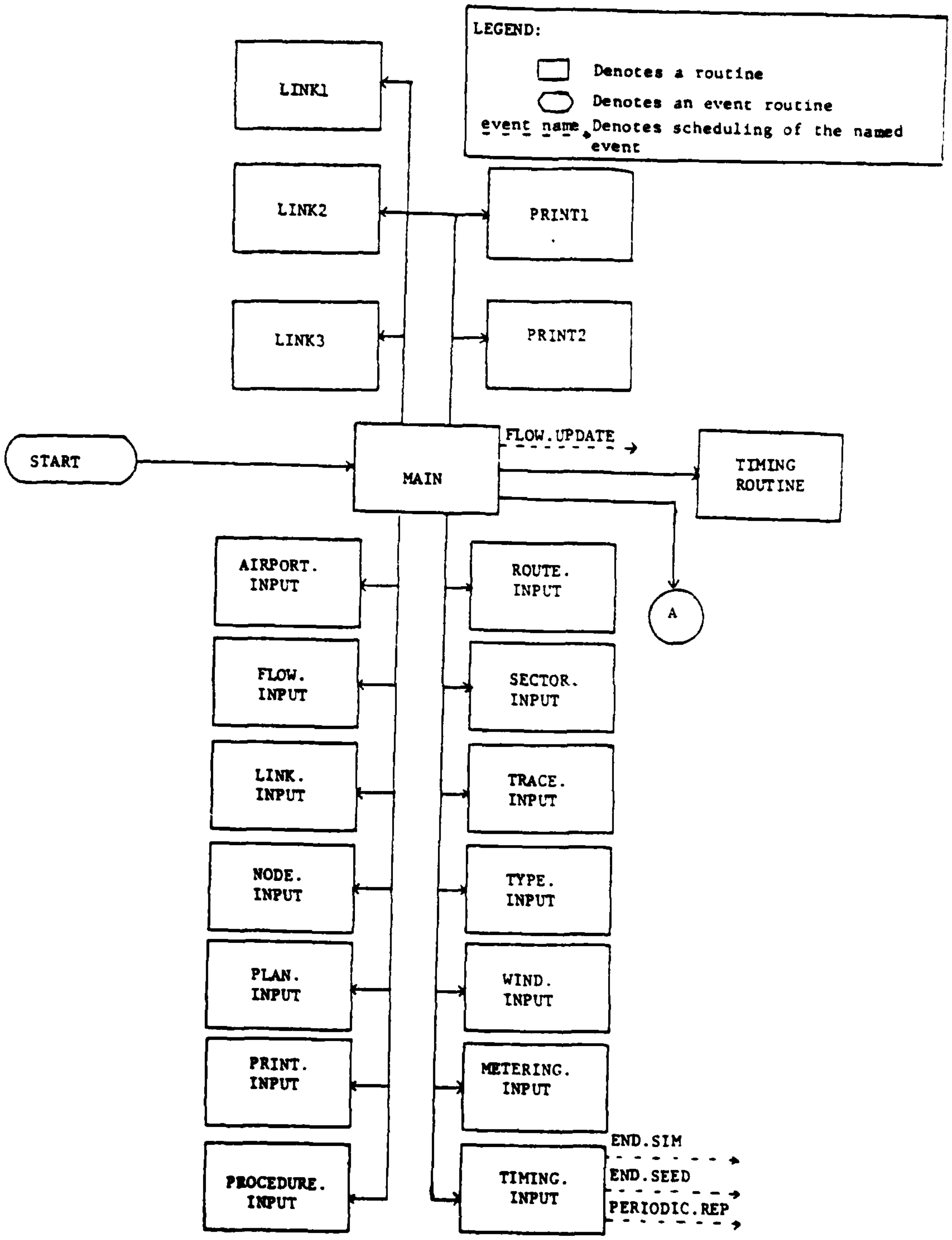

FIGURE 8. FLOWCHART OF AADM INPUT LOGIC

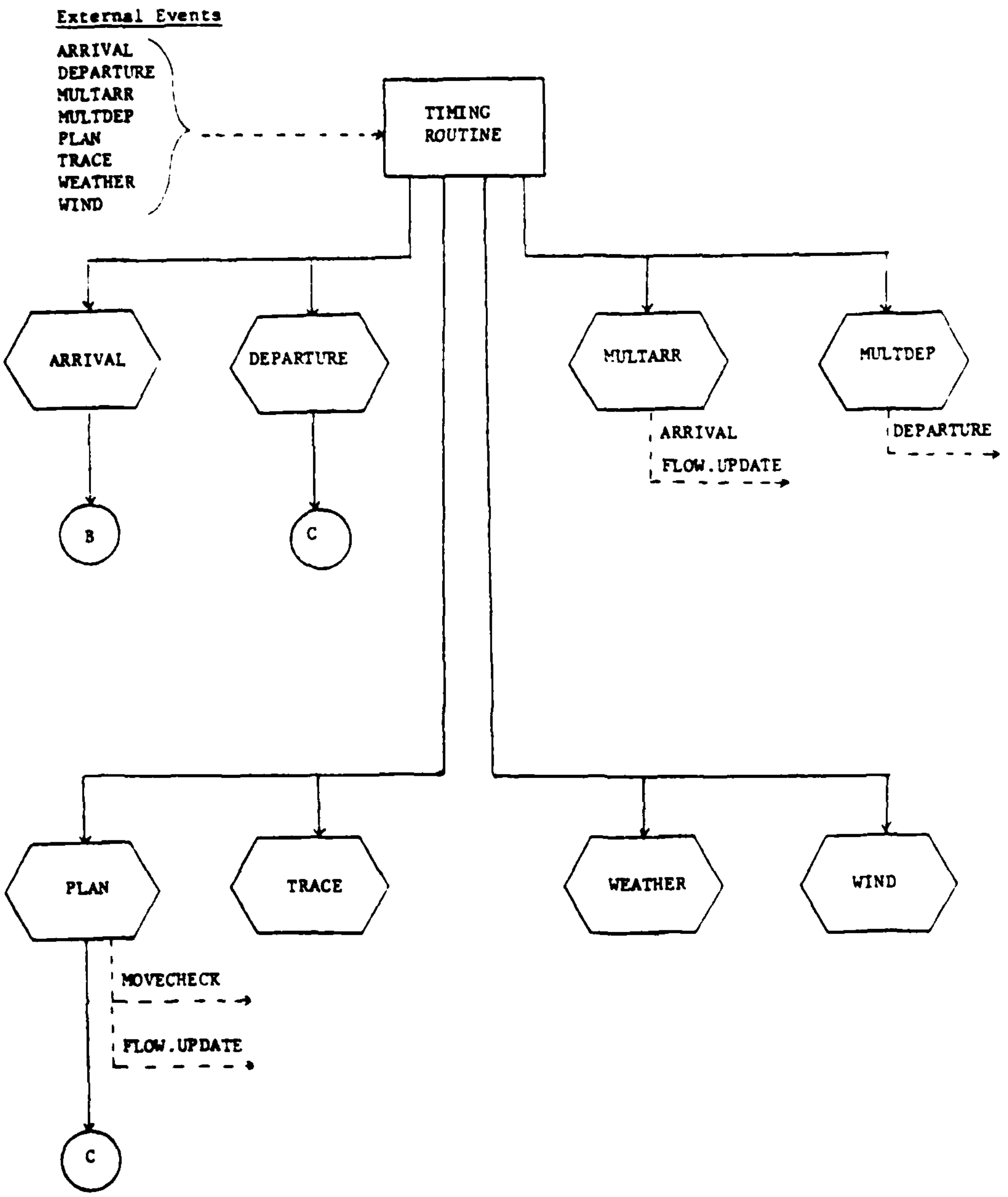

FIGURE 9. FLOWCHART OF AADM EXTERNAL EVENT PROCESSING LOGIC

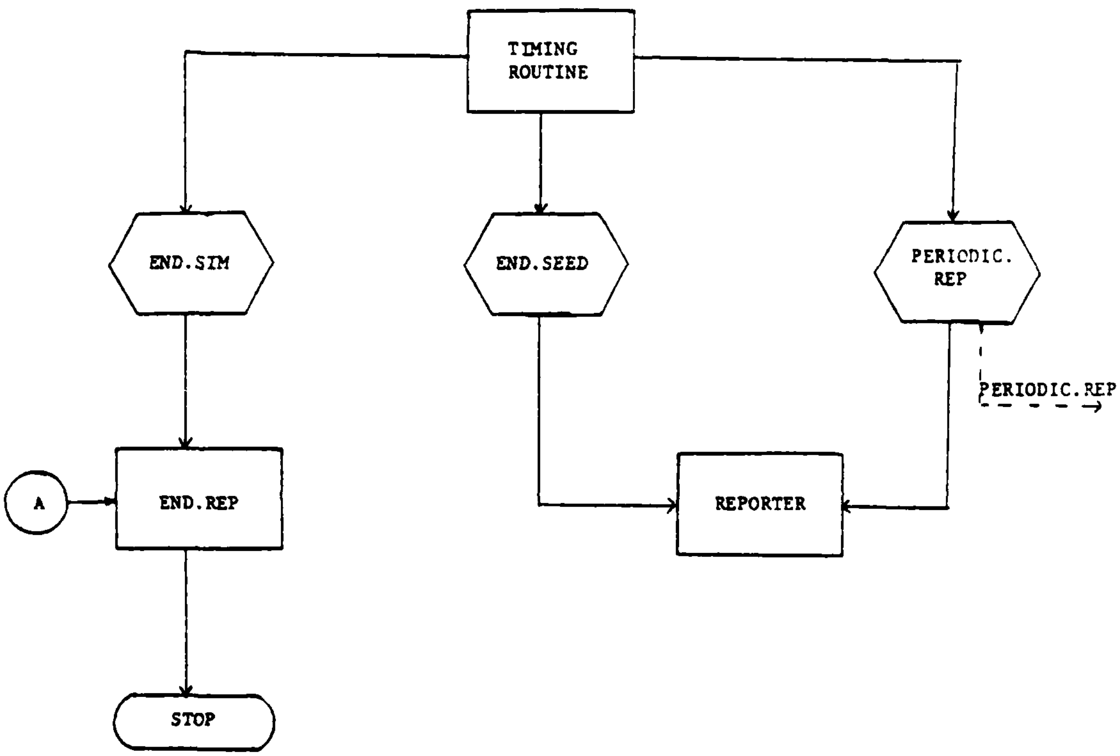

FIGURE 10. FLOWCHART OF AADM SIMULATION REPORT LOGIC

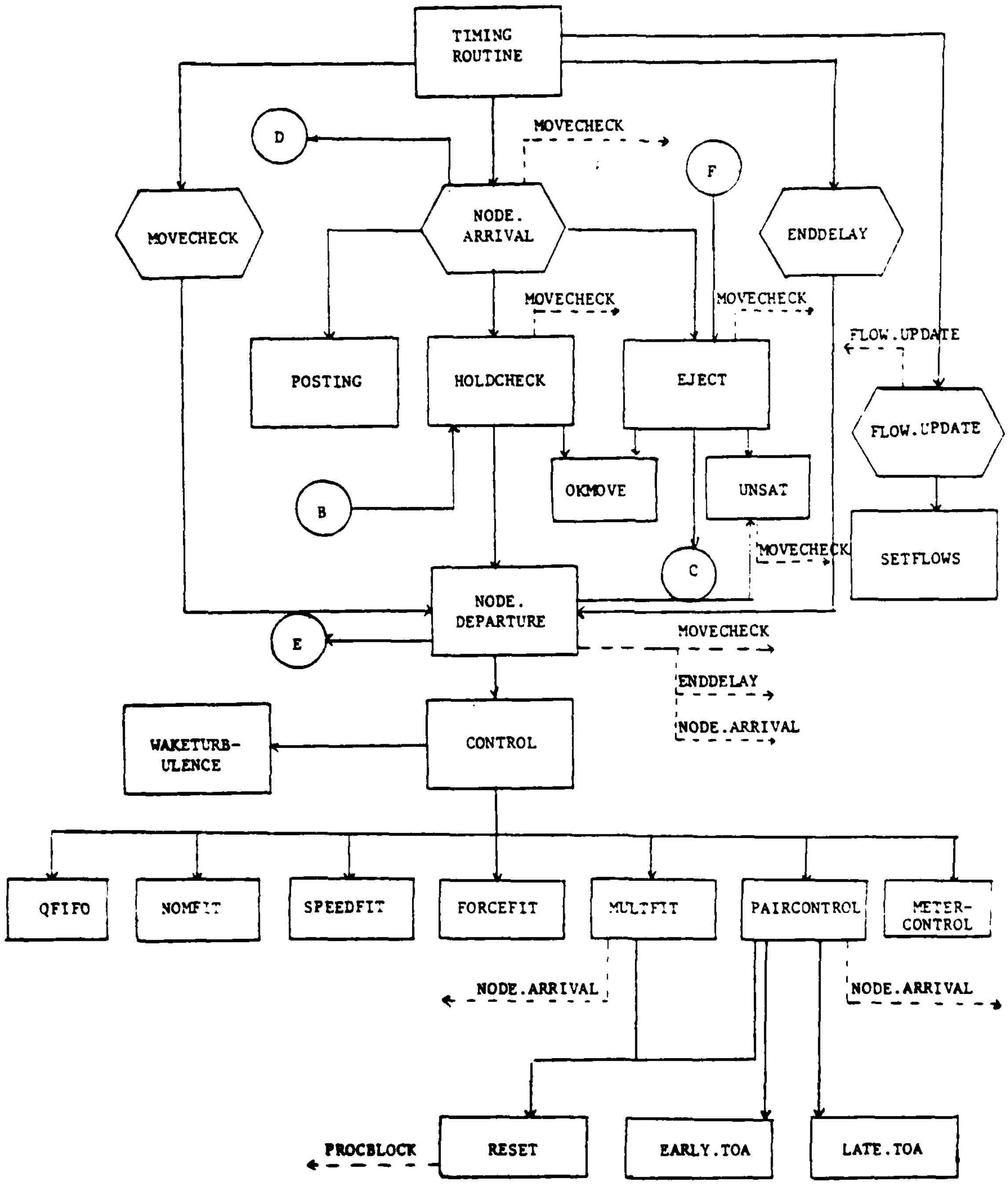

FIGURE 11. FLOWCHART OF AADM AIRSPACE TRAFFIC CONTROL LOGIC

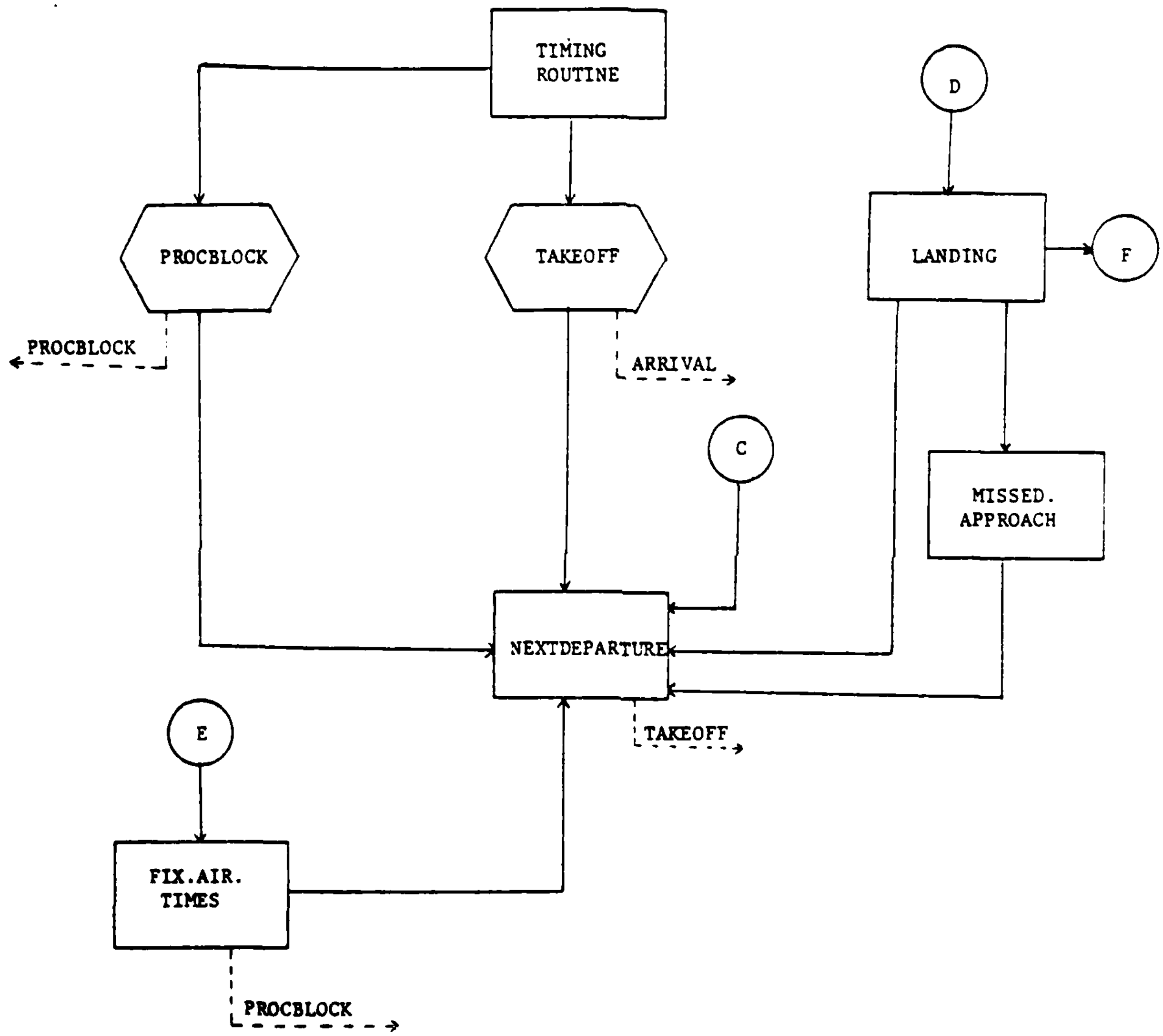

FIGURE 12. FLOWCHART OF AADM AIRPORT/AIRSPACE INTERFACE LOGIC

program execution. The major function of MAIN is to control reading of the input data, processing of the data into the form required to perform the simulation, and printing of the input data for user reference and verification.

The input data to AADM are grouped into 14 categories, four of which are required. Each category is preceded by a keyword which triggers a call to an appropriate input routine which reads and processes the type of data in the category. Each keyword, the input routine associated with the keyword, and whether or not the data category is required are given in Table 1.

The keyword "GO" is inserted at the end of the input data. When this keyword is encountered the data for all the previous input sections are linked by routines LINK1, LINK2, and LINK3. PRINT1 and PRINT2 are then called to print a version of the input data in a format to facilitate user reference and checking. MAIN then schedules the first FLOW.UPDATE event if Level III is being used. The simulation is then started and control of the program is passed to the TIMING ROUTINE, an internal SIMSCRIPT routine which controls simulation timing and event processing. The TIMING ROUTINE keeps track of all scheduled events and triggers the execution of events in proper time sequence. When an event occurs, the event routine with the same name as the event is executed. This event routine can call upon other logical routines as necessary.

Table 1

INPUT DATA CATEGORIES

Keyword	Required	Input Routine
AIRPORTS	No	AIRPORT.INPUT
FLOWS	No	FLOW.INPUT
LINKS	Yes	LINK.INPUT
NODES	Yes	NODE.INPUT
PLANS	No	PLAN.INPUT
PRINT	No	PRINT.INPUT
PROCEDURES	No	PROCEDURE.INPUT
ROUTES	Yes	ROUTE.INPUT
SECTORS	No	SECTOR.INPUT
TRACE	No	TRACE.INPUT
AIRCRAFT	Yes	TYPE.INPUT
WIND	No	WIND.INPUT
METERING	No	METERING.INPUT
TIMING	No	TIMING.INPUT

C. External Event Processing Logic

The external events for the simulation are specified by the user at the end.of the input data file. The time each event is to occur as well as the parameters associated with each event are read. The interval SIMSCRIPT TIMING ROUTINE schedules and executes each of these events at the specified time by exercising an event routine with the same name as the event.

A flowchart of the logical segment for processing these events is shown in Figure 9. Since the ARRIVAL event deals with an aircraft entering the airspace, the ARRIVAL event routine is coupled to the ATC simulation logic for determining aircraft movement. Similarly, since a DEPARTURE event involves an aircraft requesting clearance to take off, the DEPARTURE event routine is coupled to the airport/airspace interface logic. Since the PLAN event may affect airport operations, the PLAN event routine is also coupled to the airport/airspace interface logic. The events that are scheduled by the various event routines are indicated by the dashed arrows. MULTARR schedules ARRIVAL and FLOW.UPDATE events, MULTDEP schedules DEPARTURE events, and PLAN schedules MOVECHECK and FLOW.UPDATE events. (Refer to the preceding description of the event routines with the same name as these events for information about their function.) The TIMING ROUTINE records all of these scheduled events and causes them to occur at the scheduled times.

D. Simulation Report Logic

The AADM program segment that controls the printing of simulation results is shown in Figure 10. Three events are included in this logic:

END.SIM, END.SEED, and PERIODIC.REP. The END.SIM event is executed if the time specified as the maximum run time for the simulation is reached. This event calls upon the END.REP routine, which prints a final report of simulation results and then stops the simulation. (See Section IV for a description of the output.) The simulation will also be ended if at any time during the simulation no events are scheduled. In this case, control of the program execution is passed to MAIN, which calls END.REP.

The END.SEED event occurs at the end of the simulation seed time. It calls upon REPORTER to print a report of simulation results during the seed period. Various statistics are reinitialized and the simulation is resumed. The PERIODIC.REP event provides printing of simulation results over time periods of simulation. The PERIODIC.REP event routine schedules the next future PERIODIC.REP event according to the user specified frequency for periodic reports.

E. Airspace Traffic Control Logic

The simulation logic of AADM is designed to simulate the movement of aircraft through an airspace by modeling three levels of traffic control:

- Level I--Tactical
- Level II--Sequencing
- Level III--Strategic.

A flowchart of the airspace traffic control logic segment is shown in Figure 11. A description of each of the three levels of control logic follows:

1. Level I—Tactical

Level I is concerned with movement of aircraft from node to node along a route. Three internal events control the logic at this level: NODE.ARRIVAL, ENDDELAY, and MOVECHECK. Event NODE.ARRIVAL performs required processing when an aircraft arrives at a node. When an aircraft arrives at a node, the node is checked to determine whether it is one at which the aircraft should be removed from the system, i.e., an airport/airspace interface node or a route exit node. In the former case, the LANDING routine in the airport/airspace interface logic segment is executed. In the latter case, EJECT is executed. The node of arrival is also checked to see if it is a "POST" node, i.e., a node to which Level II looks ahead in an effort to resolve future conflicts. If so, POSTING is called to remove the aircraft from future Level II considerations at the node.

Routine HOLDCHECK checks on several conditions that would require the aircraft to go into holding at its current node position. First of all, if the holding queue of the node is not empty, the aircraft is placed at the end of the queue. The aircraft is placed at the head of an empty queue if the next link on its route is filled, if the status of the holding queue of the next node will not allow aircraft movement, or if the next sector is filled. If the next sector is filled, the holding node is placed on a list of pending nodes, whose holding queues are processed when the sector becomes unsaturated.

If the aircraft is not required to hold based on any of the above constraints, NODE.DEPARTURE is called. This routine attempts to find a

legal aircraft movement using the control strategy specified for the next node. If the aircraft cannot proceed toward the next node along its route without violating a constraint even under all allowable control actions, it is placed at the head of the holding queue and an ENDDELAY event is scheduled for that holding queue. If a legal movement is found, a NODE. ARRIVAL event is scheduled for the aircraft at the next node. In any case, the holding queues of both the current node and the node the aircraft just left are checked for possible movement as a result of this aircraft arrival.

Events ENDDELAY and MOVECHECK are both scheduled as a result of holding conditions at a node. When executed, they cause the holding queue at a node to be checked for aircraft that may be moved. If a potential legal movement is detected, routine NODE.DEPARTURE is called.

In the AADM program, an arrival queue is maintained for each node in the airspace being modeled. The arrival queue for a node is a list of all aircraft on links terminating at the node, with the list ordered by projected times of arrival at the node. Routine CONTROL is exercised to determine the placement of the aircraft in the arrival queue of the next node along its route and to initiate any control actions required to ensure that safe separation and operating standards are met. Control actions include speed changes, vectoring, path-stretching, and holding of aircraft. The strategy to be used in placing an aircraft in an arrival queue at each node is a user input. CONTROL draws upon several routines in implementing the various control strategies. These routines include:

- WAKETURB
- NOMFIT
- QFIFO
- SPEEDFIT
- MULTFIT
- FORCEFIT.

A brief description of each of these routines will be provided before describing the six arrival strategies. For the purposes of this description, assume that an aircraft is arriving on a link and attempts are being made to determine an appropriate position of order for this arriving aircraft on the arrival queue of the node at which the link terminates.

On certain links in the airspace, it may be desirable to maximize the capacity of the link by avoiding the placement of a light aircraft behind a heavy aircraft, since increased separation requirements would be needed due to waketurbulence. The WAKETURB routine determines the preferred placement of an arriving aircraft in the arrival queue on the basis of waketurbulence separation requirements.

The NOMFIT routine places the aircraft in the arrival queue at the position of order at which it "normally" would arrive without any control actions, if a conflict would not result. The nominal position is based on the arrival time of the aircraft at the node assuming it travels the link at the user input nominal speed for the link for that aircraft.

The QFIFO routine places the aircraft last in the arrival queue, initiating any control actions required to resolve conflicts. All control actions are imposed on the entering aircraft.

The SPEEDFIT routine attempts to place the aircraft at a given position of order in the arrival queue. Only control actions (e.g., speed changes, vectoring, holding) on the entering aircraft are considered.

The MULTFIT routine attempts to place the aircraft at a specified position in the arrival queue by controlling the entering aircraft and the aircraft preceeding and following it on the queue. Attempts to resolve conflicts include controlling the entering and preceeding aircraft, then the entering and succeeding aircraft, and finally all three aircraft.

The FORCEFIT routine places an aircraft at a specified position in the queue. Conflicts are resolved by controlling the entering aircraft, its predecessor in the arrival queue and as many succeeding aircraft as necessary.

Each of the six control strategies currently call upon these routines in a series of steps. The steps are executed successively until the aircraft is placed in the queue with all conflicts resolved. The steps for each strategy are as follows:

Strategy 1

Use QFIFO.

Strategy 2

(1) Try NOMFIT at the nominal arrival position in the queue.

(2) Try SPEEDFIT at the nominal arrival position in the queue.

(3) Try SPEEDFIT at each successively earlier arrival position in the queue.

(4) Try SPEEDFIT at each successively later arrival position in the queue.

Strategy 3

(1) Try NOMFIT at the nominal arrival position.

(2) Try SPEEDFIT at the nominal arrival position.

(3) Try MULTFIT at the nominal arrival position.

(4) Repeat steps (2) and (3) for each successively earlier arrival position in the queue.

(5) Repeat steps (2) and (3) for each successively later arrival position in the queue.

Strategy 4*

(1) Try NOMFIT at the nominal arrival poisition.

(2) Try SPEEDFIT at the nominal arrival poisition.

(3) Try MULTFIT at the nominal arrival position.

(4) Use FORECFIT at the nominal arrival position.

Strategy 5

(1) Try NOMFIT at the nominal arrival position if WAKETURB indicates this to be a desirable position.

(2) Try SPEEDFIT at the nominal arrival position if WAKETURB indicates this to be a desirable position (with no path-stretching or holding permitted).

(3) Try SPEEDFIT at each successively earlier arrival position in the queue at which WAKETURB indicates a desirable position (with no path-stretching or holding permitted).

(4) Try SPEEDFIT at each successively later arrival position in the queue at which WAKETURB indicates a desirable position (with no path-stretching or holding permitted).

(5) Use Strategy 2.

---

*This strategy is not currently operational because FORCEFIT is not yet coded.

(1) Try NOMFIT at the nominal arrival position if WAKETURB indicates this to be a desirable position.

(2) Try SPEEDFIT at the nominal arrival position if WAKETURB indicates this to be a desirable position (with no path-stretching or holding permitted).

(3) Try MULTFIT at the nominal arrival position if WAKETURB indicates this to be a desirable position (with no path-stretching or holding permitted).

(4) Repeat steps (2) and (3) for each successively earlier arrival position in the queue at which WAKETURB indicates a desirable position.

(5) Repeat steps (2) and (3) for each successively later arrival position in the queue at which WAKETURB indicates a desirable position.

(6) Use Strategy 3.

The number of strategies that can be linked to the CONTROL routine is unlimited. The modular design of the program allows addition of other alternative strategies which are identified.

The PAIRCONTROL routine provides special control logic for controlling aircraft in pairs along mated links. This is useful in simulating such operations as final approach to closely-spaced parallel runways under VFR conditions. If two links are designated as mates, control actions are taken to try to have a pair of aircraft (one on each of the mated links) arrive at the terminal nodes of their links at about the same time. Aircraft are paired, if possible, on the links feeding the mated links.

Control actions taken specifically to bring the paired aircraft closer together (in terms of arrival times at the terminal nodes of the mated links) are restricted to maintaining the aircraft in their current position in their node arrival queues and only involve the aircraft in the pair.

2. Level II--Sequencing

Level I control of an aircraft is concerned with moving an aircraft to the next node along its route. Level II is concerned with resolving conflicts at nodes beyond the next node on its route. This level of control is optional. To specify Level II, the user designates certain nodes or "POST" nodes. These are generally bottlenecks or critical merge points in the airspace route network. For each of these POST nodes a set of "METER" nodes is designated. METER nodes are nodes through which traffic must pass on the way to the POST node. When an aircraft is on any link between a METER node and its associated POST node, it is subject to Level II control actions (if it is on a route designated as one on which traffic should be controlled at Level II).

The Level II control strategy logic is contained in routine METERCON. Each time an aircraft subject to Level II control arrives at a node, Level I control logic is exercised to determine its movement to the next node along the route. Then METERCON is called to provide a "look-ahead" at the next POST node along the route. This routine projects the status of traffic at the POST at the future time that the aircraft would arrive there, assuming nominal speed beyond the next node. All traffic converging on the POST node is considered in this "look-ahead." If a future conflict with another aircraft is projected, control actions are taken to fully or partially alleviate the conflict. In this

strategy, Level II control actions are limited to controlling the aircraft currently under consideration and maintaining it in the position in the node arrival queue determined at Level I.

Although only one Level II strategy has been programmed to date, the modular design of the program allows for additional strategies to be easily added.

3. <u>Level III--Strategic</u>

Level III control is concerned with placing strategic constraints on traffic flow in terms of separation distances at nodes. These constraints are aimed at balancing the flow of traffic into the modeled airspace to prevent congestion problems from occurring which cannot be reasonably handled at Levels I and II. Level III control is optional within the AADM program.

The Level III separation constraints require updating as traffic loading and airport operating status change. The event FLOW.UPDATE triggers the resetting of Level III separation distances. This event occurs periodically at a user-specified frequency. In addition, PLAN and MULTARR events trigger FLOW.UPDATE events.

Although AADM is programmed to allow many Level III control strategies, one strategy has been programmed to date. The logic for this strategy is contained in routine SETFLOWS. To specify this Level III control, the user defines FLOWPOST nodes. These are generally bottlenecks or critical merge points in the route network. Associated with each FLOWPOST is a set of FLOWMETER nodes. These are entry nodes to the airspace that feed traffic to the FLOWPOST. Also specified are such parameters as the average speed

of traffic flowing through each FLOWPOST and FLOWMETER node and the minimum, maximum, and increment for the allowable separation distance settings at each FLOWMETER node.

When a FLOW.UPDATE event occurs, the number of aircraft expected to flow through each FLOWPOST during the time period until the next FLOW.UPDATE is computed. Likewise, the number of aircraft expected to nominally arrive at each of the associated FLOWMETER nodes is computed. In-trail separation distances at each of the FLOWMETER nodes are set so that the flow through the FLOWPOST node equals the sum of the flows through the associated FLOWMETER nodes. The flows set for the FLOWMETER nodes are proportional to the traffic loadings at the nodes.

F. Airport/Airspace Interface Logic

A flowchart of the airport/airspace interface logic segment of the AADM program is shown in Figure 12. This logical segment is concerned with simulating the movement of aircraft and control actions at or near the airport, including final approach, landing, and departure operations. As seen from Figures 11 and 12, coupling between the airspace traffic control and airport/airspace interface logic exists to simulate the interaction between airspace and airport operations.

There are two internal events which drive the airport/airspace interface logic: TAKEOFF and PROCBLOCK. In addition, a NODE.ARRIVAL event (see Figure 11) triggers the LANDING routine when an aircraft arrives at an airport node. The LANDING routine contains logic for simulating an aircraft landing attempt. The first logical step in this routine is to check to see if the aircraft can be cleared to land. If the runway visual range

is insufficient, the ceiling is too low, or a previous landing or departure conflicts with necessary runway clearance, the aircraft is not cleared to land. In this case, a missed approach must be executed, so routine MISSED.APPROACH is called. If the aircraft is cleared to land, constraints on the occurrence of subsequent landing and departure procedures are updated. Routine EJECT is then called to purge the aircraft from the airspace system. Routine NEXTDEPARTURE is then called to determine the next aircraft to be considered for departure at the airport and to schedule a TAKEOFF event for it. In fact, NEXTDEPARTURE is called whenever anything transpires that may affect the next departure to occur at an airport.

The TAKEOFF event routine contains logic to simulate an aircraft takeoff. When a TAKEOFF event occurs, a set of checks is performed to ensure that the associated aircraft can be cleared to roll. If a previous landing or departure conflicts with necessary runway clearance, if a route separation restriction for departures is violated, if departure restrictions are in effect because of an airport plan change, if airspace congestion is present on the departure route, or if an arriving aircraft is too close to the airport, the pending takeoff is not cleared. If all conditions for a safe takeoff are met, the aircraft is cleared to roll, constraints on the occurrence of subsequent landing and departure procedures are updated, and an ARRIVAL event is scheduled to occur at the time the departing aircraft will lift off and enter the airspace. Routine NEXTDEPARTURE is then called upon to schedule the next potential TAKEOFF at the airport.

Event PROCBLOCK triggers the setting of constraints which prevent departure procedures from occurring when an aircraft on final approach is

too close to the airport. When an aircraft enters the final approach link, routine FIX.AIR.TIMES schedules a PROCBLOCK event at the time the aircraft will be at a point along the approach path where departure procedures begin to become restricted. Since various departure procedures may be restricted at different distances from the airport, succeeding PROCBLOCK events are scheduled as necessary as the aircraft progresses toward the airport.

In addition to scheduling PROCBLOCK events, the FIX.AIR.TIMES routine sets constraints on departures to reflect airspace separation requirements among departing aircraft. These requirements include wake turbulence separations and route separation restrictions.

IV OUTPUT OF SIMULATION RESULTS

Three types of output are provided by the AADM simulation: input data messages, simulation log, and simulation reports. A description and an example of each of these types of output follow.

A. Input Data Messages

In the routines which read and process the input data, many checks have been programmed to test the consistency of the input data. Error and warning messages are printed to notify the user of the results of these checks. A listing of these error and warning messages is shown in Table 2. Warnings result in corrective actions to ensure a simulation run. The corrective actions are stated in the explanations of the warnings. Errors will result in the program being terminated after the input phase of the program is completed and no simulation will be run.

B. Simulation Log

A second type of output from AADM is a detailed log of the simulation. An example of portions of a simulation log is provided in Table 3. Information on the progress of each aircraft through the modeled system is printed. The time (in hours) is given, followed by a description of the occurrence or control action.

The simulation log can be very useful for program debugging as well as for detailed tracking of aircraft through the airspace/airport system. This output is optional and may be turned on and off at will during the simulation by use of the TRACE event.

Table 2

ERROR AND WARNING MESSAGES

NO.	TYPE	EXPLANATION
1	WARNING	A LINK ON A SECTOR LINK LIST IS UNDEFINED. NO ACTION IS TAKEN.
2	WARNING	A LINK IS NOT FOUND ON ANY SECTOR LINK LIST. IT IS PLACED IN THE FIRST MODELED SECTOR.
3	WARNING	THE TO OR FROM NODE OF A LINK IS UNDEFINED. CORRECTIVE ACTION WILL BE TAKEN IF THE LINK IS SPECIFIED IN A ROUTE.
4	ERROR	A NODE USED IN A ROUTE DEFINITION IS UNDEFINED. THE ROUTE BECOMES UNDEFINED; AN AIRCRAFT PLACED ON SUCH A ROUTE WILL PRODUCE AN INFORMATORY MESSAGE. AN AIRCRAFT'S ROUTE WILL NOT BE CHANGED TO AN UNDEFINED ROUTE AS A RESULT OF A PLAN CHANGE.
5	ERROR	A CONNECTING LINK REQUIRED IN A ROUTE DEFINITION IS UNDEFINED. CORRECTIVE ACTION IS THE SAME AS ERROR 4.
6	ERROR	THE FIRST ROUTE ON A PLAN CARD IS UNDEFINED. THE CARD IS IGNORED.
7	ERROR	A POST NODE IS UNDEFINED. NO METERING IS PERFORMED AT ANY METERING NODE ASSOCIATED WITH THAT POST.
8	ERROR	A METERING NODE IS UNDEFINED. NO METERING IS PERFORMED AT ANY NODE FOR THE ASSOCIATED POST.
9	WARNING	A ROUTE SPECIFIED AT A METERING NODE IS UNDEFINED. NO ACTION IS TAKEN.
10	WARNING	TOO MANY MAXIMUM SPEEDS ARE DEFINED FOR AN AIRCRAFT. TYPE. THE EXCESS ARE IGNORED.
11	WARNING	TOO MANY MINIMUM SPEEDS ARE DEFINED FOR AN AIRCRAFT TYPE. THE EXCESS ARE IGNORED.
12	WARNING	THE AMOUNT OF SEPARATION DATA INPUT FOR A PARTICULAR AIRCRAFT TYPE IS INCONSISTENT WITH THE NUMBER OF AIRCRAFT TYPES. EXCESS SEPARATION DATA IS IGNORED. IF TOO LITTLE DATA IS PROVIDED, THE UNDEFINED SEPARATIONS ARE SET TO 3 MILES.
13	WARNING	A LINK TYPE IS HIGHER THAN THAT SPECIFIED IN THE AIRCRAFT TYPE SPEED DATA. THE TYPE IS SET TO 1.
14	WARNING	A ROUTE SPECIFIED AT A METERING OR FLOWMETER NODE IS NOT DEFINED AT THE NODE. NO ACTION IS TAKEN.

Table 2 (Concluded)

15	WARNING	A LINK ON A WIND LIST IS UNDEFINED., NO ACTION IS TAKEN.
16	WARNING	A LINK IS NOT FOUND ON ANY WIND LIST. IT IS PLACED IN WINDSET 1.
17	WARNING	MORE THAN ONE AIRCRAFT HAS THE SAME MAXIMUM SEPARATION. THE FIRST ONE FOUND IS CHOSEN AS THE THE HEAVY TYPE.
18	ERROR	A ROUTE ON A PLAN CARD IS UNDEFINED. THE MAIN ROUTE REMAINS AT ITS PLAN 1 DEFINITION FOR THAT PLAN.
19	ERROR	A METER NODE OR NODE INTERNAL TO A METER CHAIN HAS BEEN PREVIOUSLY DEFINED AS A METER NODE OR PART OF A METER CHAIN. THIS IS A FATAL ERROR.
20	ERROR	A DUPLICATE POST NODE HAS BEEN FOUND. THIS IS A FATAL ERROR.
21	ERROR	MORE THAN ONE MATE HAS BEEN SPECIFIED FOR THE SAME LINK. THIS IS A FATAL ERROR.
22	ERROR	A LINK USED AS A MATE IS UNDEFINED. THIS IS A FATAL ERROR.
23	ERROR	A NODE USED IN AN AIRPORT DEFINITION IS UNDEFINED.
24	ERROR	NO ARRIVAL OR DEPARTURE PROCEDURES HAVE BEEN DEFINED FOR A NODE USED IN AN AIRPORT DEFINITION.
25	ERROR	A PLAN USED IN DEFINING ARRIVAL OR DEPARTURE PROCEDURES FOR AN AIRPORT IS UNDEFINED.
26	ERROR	AN ARRIVAL PROCEDURE USED IN AN AIRPORT DEFINITION IS UNDEFINED.
27	ERROR	A DEPARTURE PROCEDURE USED IN AN AIRPORT DEFINITION IS UNDEFINED.
28	WARNING	A PLAN USED IN DEFINING ROUTE SEPARATIONS IS UNDEFINED.
29	WARNING	NOT ENOUGH TIME OR DISTANCE DATA HAS BEEN FOUND IN A PROCEDURE DEFINITION. THE REMAINING DATA POSITIONS IS FILLED WITH DEFAULT DATA.
30	WARNING	TOO MUCH TIME OR DISTANCE DATA HAS BEEN FOUND IN A PROCEDURE DEFINITION. THE EXCESS DATA IS IGNORED.
31	WARNING	AN AIRCRAFT TYPE USED IN A PROCEDURE DEFINITION IS UNDEFINED.
32	ERROR	A DUPLICATE FLOWPOST HAS BEEN FOUND. THIS IS A FATAL ERROR.
33	ERROR	THE NUMBER OF TIME AND DISTANCE ELEMENT IN A PROCEDURE DEFINITION IS NOT DIVISIBLE BY 2. NO MORE PROCEDURE INPUT IS READ, AND NO PROCEDURES ARE DEFINED. THIS MAY GIVE RISE TO ERRORS 26 AND 27.
34	WARNING	A FLOWPOST NODE IS UNDEFINED. NO FLOW CONTROL IS PERFORMED AT ANY FLOWMETER ASSOCIATED WITH THIS FLOWPOST.
35	WARNING	A FLOWMETER NODE IS UNDEFINED. NO ACTION IS TAKEN.
36	WARNING	A ROUTE SPECIFIED AT A FLOWMETER NODE IS UNDEFINED. NO ACTION IS TAKEN.
37	WARNING	A ROUTE SPECIFIED AT A FLOWMETER NODE DOES NOT BEGIN AT THIS NODE. NO ACTION IS TAKEN.
38	ERROR	A ROUTE HAS BEEN SPECIFIED FOR MORE THAN ONE FLOWMETER. THIS IS A FATAL ERROR.
39	WARNING	THE PLAN FIX NODE DOES NOT EXIST. THE PARAMETER IS NOT SET FOR THAT ROUTE.

Table 3

SAMPLE SIMULATION LOG OUTPUT

```
TIME   .41; C    AIRCRAFT ON ROUTE  16 ARRIVED AT NODE  35
TIME   .41; NODE  35 HOLDCHECK
TIME   .41; AT NODE  35; NEW LINK  49, NEW NODE  36
TIME   .41; C    AIRCRAFT ON ROUTE  16 IN NODE.DEP AT  35
TIME   .41; (NOMFIT) C      PLACED BETWEEN C      AND
            SPEED 250.0, TOA   .47, VECTORDELAY  0.
TIME   .41; (METERCON) C      PLACED IN METERING AT NODE   39 WITH
             METERTIME    .47
TIME   .41; (PAIRCONTROL)
TIME   .41; DEPARTURE AT NODE  35 FOR NODE  36
TIME   .41; NODE  35 MOVECHECK
TIME   .41; C    AIRCRAFT ON ROUTE  16 IN NODE.DEP AT  34
TIME   .41; (NOMFIT) C      PLACED BETWEEN C      AND
            SPEED 250.0, TOA   .47, VECTORDELAY  0.
TIME   .41; (METERCON) C      PLACED IN METERING AT NODE   39 WITH
             METERTIME    .53
TIME   .41; DEPARTURE AT NODE  34 FOR NODE  35
TIME   .42; C    AIRCRAFT ON ROUTE   1 ARRIVED AT NODE  15
TIME   .42; C    AIRCRAFT REMOVED FROM ROUTE   1 AT NODE  15
TIME   .42; C    AIRCRAFT ON ROUTE  11 ARRIVED AT NODE   2
TIME   .42; AIRCRAFT C      LANDING AT NODE     2
TIME   .42; C    AIRCRAFT REMOVED FROM ROUTE  11 AT NODE   2
TIME   .42; NEXT DEPARTURE AT AIRPORT SFO   IS BY AIRCRAFT C      ON
            ROUTE      2 USING PROCEDURE     3
TIME   .42; C    AIRCRAFT ON ROUTE  16 ARRIVED AT NODE   1
TIME   .42; AIRCRAFT C      LANDING AT NODE     1
TIME   .42; C    AIRCRAFT REMOVED FROM ROUTE  16 AT NODE   1
TIME   .42; NEXT DEPARTURE AT AIRPORT SFO   IS BY AIRCRAFT C      ON
            ROUTE      2 USING PROCEDURE     3 AT TIME   .43
TIME   .42; C    AIRCRAFT ON ROUTE  10 ARRIVED AT NODE 924
TIME   .42; C    AIRCRAFT REMOVED FROM ROUTE  10 AT NODE 924
TIME   .43; D    AIRCRAFT ON ROUTE  11 ARRIVED AT NODE  37
TIME   .43; NODE  37 HOLDCHECK
TIME   .43; AT NODE  37; NEW LINK  51, NEW NODE   2
TIME   .43; D    AIRCRAFT ON ROUTE  11 IN NODE.DEP AT  37
TIME   .43; SPEED 134.6, TOA   .50, VECTORDELAY  0.
TIME   .43; (PAIRCONTROL)
TIME   .43; DEPARTURE AT NODE  37 FOR NODE   2
TIME   .43; C    AIRCRAFT ON ROUTE  16 ARRIVED AT NODE  36
TIME   .43; NODE  36 HOLDCHECK
TIME   .43; AT NODE  36; NEW LINK  50, NEW NODE   1
TIME   .43; C    AIRCRAFT ON ROUTE  16 IN NODE.DEP AT  36
TIME   .43; SPEED 140.0, TOA   .50, VECTORDELAY  0.
TIME   .43; (PAIRCONTROL)
TIME   .43; RESET C     ; SPEED 134.6, TOA   .50, VECDELAY  0.  , METTIME  0.
TIME   .43; DEPARTURE AT NODE  36 FOR NODE   1
```

Table 3 (Concluded)

```
TIME   .89; C    AIRCRAFT INJECTED ON ROUTE   17 AT NODE   45
TIME   .89; NODE  45 HOLDCHECK
TIME   .89; AT NODE  45; NEW LINK  57, NEW NODE  46
TIME   .89; C    AIRCRAFT ON ROUTE  17 IN NODE.DEP AT  45
TIME   .89; (EMPTY) SPEED 250.0, TOA   .95, VECTORDELAY  0.
TIME   .89; (METERCON) C     PLACED IN METERING AT NODE   50 WITH
              METERTIME   .99
TIME   .89; DEPARTURE AT NODE  45 FOR NODE  46
TIME   .89; C    AIRCRAFT INJECTED ON ROUTE    9 AT NODE   12
TIME   .89; NODE  12 HOLDCHECK
TIME   .89; AT NODE  12; NEW LINK  21, NEW NODE  23
TIME   .89; C    AIRCRAFT ON ROUTE   9 IN NODE.DEP AT  12
TIME   .89; (EMPTY) SPEED 200.0, TOA   .90, VECTORDELAY  0.
TIME   .89; DEPARTURE AT NODE  12 FOR NODE  23
TIME   .89; AIRCRAFT C     TAKING OFF FROM AIRPORT SFO   ON
            ROUTE     2 USING PROCEDURE      3
TIME   .89; NEXT DEPARTURE AT AIRPORT SFO   IS BY AIRCRAFT B     ON
            ROUTE     3 USING PROCEDURE      4 AT TIME   .89
TIME   .89; AIRCRAFT B     TAKING OFF FROM AIRPORT SFO   ON
            ROUTE     3 USING PROCEDURE      4
TIME   .89; NEXT DEPARTURE AT AIRPORT SFO   IS BY AIRCRAFT C     ON
            ROUTE     2 USING PROCEDURE      3
TIME   .89; (PROCBLOCK) AIRCRAFT D     IS NOW WITHIN   2.00 MI.
              OF AIRPORT SFO   . PROCEDURES BEING BLOCKED ARE:
                 3
                 4
                 5
                 6
TIME   .89; NEXT DEPARTURE AT AIRPORT SFO   IS BY AIRCRAFT C     ON
            ROUTE     2 USING PROCEDURE      3
TIME   .90; C    AIRCRAFT INJECTED ON ROUTE   18 AT NODE   38
TIME   .90; NODE  38 HOLDCHECK
TIME   .90; AT NODE  38; NEW LINK  52, NEW NODE  39
TIME   .90; C    AIRCRAFT ON ROUTE  18 IN NODE.DEP AT  38
TIME   .90; (EMPTY) SPEED 250.0, TOA   .96, VECTORDELAY  0.
TIME   .90; (METERCON) C     PLACED IN METERING AT NODE   50 WITH
              METERTIME  1.03
TIME   .90; DEPARTURE AT NODE  38 FOR NODE  39
TIME   .90; (SETFLOWS)
            NODE    25 SEPARATION DISTANCE  10.00
            NODE    26 SEPARATION DISTANCE   5.00
            NODE    27 SEPARATION DISTANCE   5.00
            NODE    30 SEPARATION DISTANCE  25.00
            NODE    32 SEPARATION DISTANCE  25.00
            NODE    34 SEPARATION DISTANCE   5.00
```

Table 4

SAMPLE SIMULATION REPORT

DELAY AND TRAVEL TIME STATISTICS (IN MINUTES):

ROUTE NUMBER	NUMBER OF AIRCRAFT	AVERAGE DELAY	AVERAGE TRAVEL TIME	TOTAL DELAY	TOTAL TRAVEL TIME
1	17	19.36	24.59	329.04	418.05
2	9	22.62	27.71	203.58	249.42
3	6	10.88	17.01	65.25	102.09
4	8	16.59	22.46	132.71	179.64
5	4	.52	5.36	2.08	21.43
6	1	0.	3.10	0.	3.10
7	1	0.	7.70	0.	7.70
8	1	2.37	9.80	2.37	9.80
9	2	0.	3.37	0.	6.75
10	2	0.	3.25	0.	6.49
11	20	2.00	17.47	40.04	349.39
12	3	.28	16.28	.83	48.83
13	3	2.34	18.08	7.02	54.23
14	8	3.28	19.80	26.27	158.43
15	1	1.22	12.70	1.22	12.70
16	14	5.77	17.98	80.72	251.75
17	5	.90	14.90	4.50	74.48
18	2	0.	15.75	0.	31.50
19	2	0.	15.92	0.	31.83
20	3	0.	16.96	0.	50.87
21	2	0.	20.33	0.	40.66
22	3	.04	11.30	.12	33.91
23	3	0.	12.54	0.	37.61
TOTALS:	120	7.46	18.17	895.74	2180.68

C. Simulation Reports

The simulation reports provide delay and travel time statistics for various periods of the simulation. An example of a simulation report is shown in Table 4. Average delay and travel time per aircraft as well as total dealy and travel time are shown by route as well as for the overall system. Delay and travel times for departure routes include time spent by aircraft on the ground awaiting departure clearance.

The frequency of simulation reports is controlled by TIMING input data. The user may choose to receive a simulation report for the seed period of the simulation. Simulation reports may also be obtained periodically during the simulation to show periodic results. A simulation report is always obtained at the end of the simulation giving cumulative results for the entire simulation excluding the seed period.

D. Additional Simulation Results

Other potentially useful information within the AADM program is readily available for printing. Examples of such information are delay and travel time for individual aircraft, departure ground delay versus airborne delay, and delay on an airport-by-airport basis.

The SIMSCRIPT language is designed to facilitate the gathering of a wide variety of statistics. Minimum effort is entailed in gathering and printing statistics such as sums, means, variances, maximums, and minimums of quantities of interest in AADM.

V SAMPLE APPLICATION

The Oakland Bay TRACON airspace and three airports at San Francisco (SFO), Oakland (OAK), and San Jose (SJC) can be used to demonstrate the application of AADM. This demonstration, which is described in this section, is intended as an illustration of AADM's use and is not a fully calibrated depiction of the traffic operation under study. The demonstration is a simplified replication of the airport and airspace system based on data collected from the TRACON and tower facilities. Travel time and delay statistics are presented below to exemplify the outputs obtainable from an AADM simulation; they do not represent empirical measurements of traffic operations.

A. System Description

Although a variety of terminal traffic plans are employed in the subject airport and airspace system to service different prevailing wind conditions, the one most frequently used is the West Plan. This plan's major arrival and departure routings to and from the three airports are shown in Figures 13 and 14, which also show the link (solid and dashed lines) and node (dots) representation used in the AADM simulation.

With reference to Figure 13, inbound routings from the northeast to SFO actually overlay those to OAK, but as separate altitudes. These routes are shown as noncoincidental in plan view for graphical convenience. In general, arrival and departure routings do not intersect each other and arrival routings to one airport do not intersect (because of geographic or altitude separations) arrival routings to the other airports. However, some departure routings do converge as indicated in Figure 14 for those outbound routes from OAK that join SFO outbound traffic.

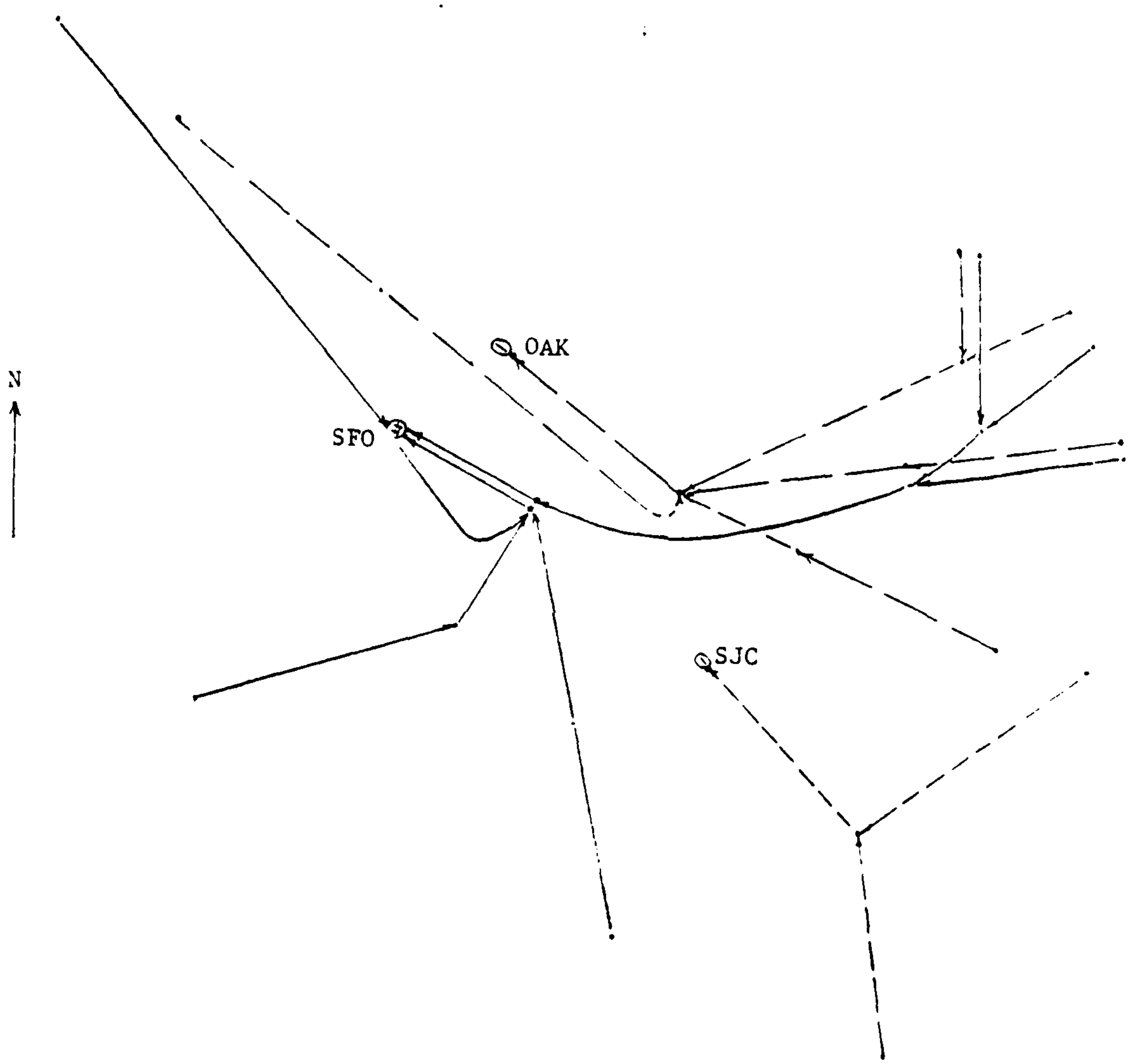

FIGURE 13. WEST PLAN ARRIVALS

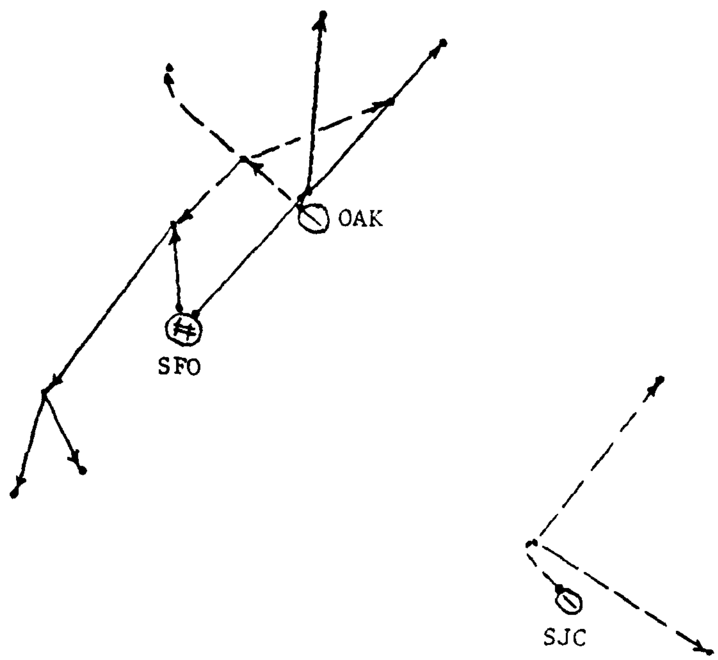

FIGURE 14. WEST PLAN DEPARTURES

The multiairport departure mergings are simulated by AADM, as are the arrival traffic merging operations. The latter involve designation of Levels II and III metering nodes at the outer boundary nodes of the route network, and designation of Levels II and III post nodes at approach fixes to the various runway configurations. SFO, which consists of two pairs of crossing parallel runways, has approach and departure links specified for each individual runway. The other two airports are modeled as single runways servicing IFR operations. Other OAK and SJC runways used by general aviation aircraft are not addressed in this sample illustration although they readily can be simulated within the AADM framework.

Another traffic plan employed in the subject system is the Southeast Plan. The simplified replication of this plan's arrival and departure traffic routings as simulated by AADM are shown in Figures 15 and 16. The links and nodes for this plan do not necessarily coincide with those of the West Plan, and Southeast Plan Levels II and III metering and post nodes are specified separately from those of the West Plan.

AADM was used to dynamically simulate a change from the West Plan to the Southeast Plan caused by a change in wind direction. The simulation required definition of transition links from one plan's routing system to that of the other. Such transition links, which are illustrated in Figure 17, enable AADM to simulate the rerouting of aircraft in the airspace during the transition period.

Additional AADM data inputs specify operational details relevant to aircraft movement, separation rules, link and node attributes, wind conditions, airport procedures, sectorization, and the like. These inputs are described later in this section.

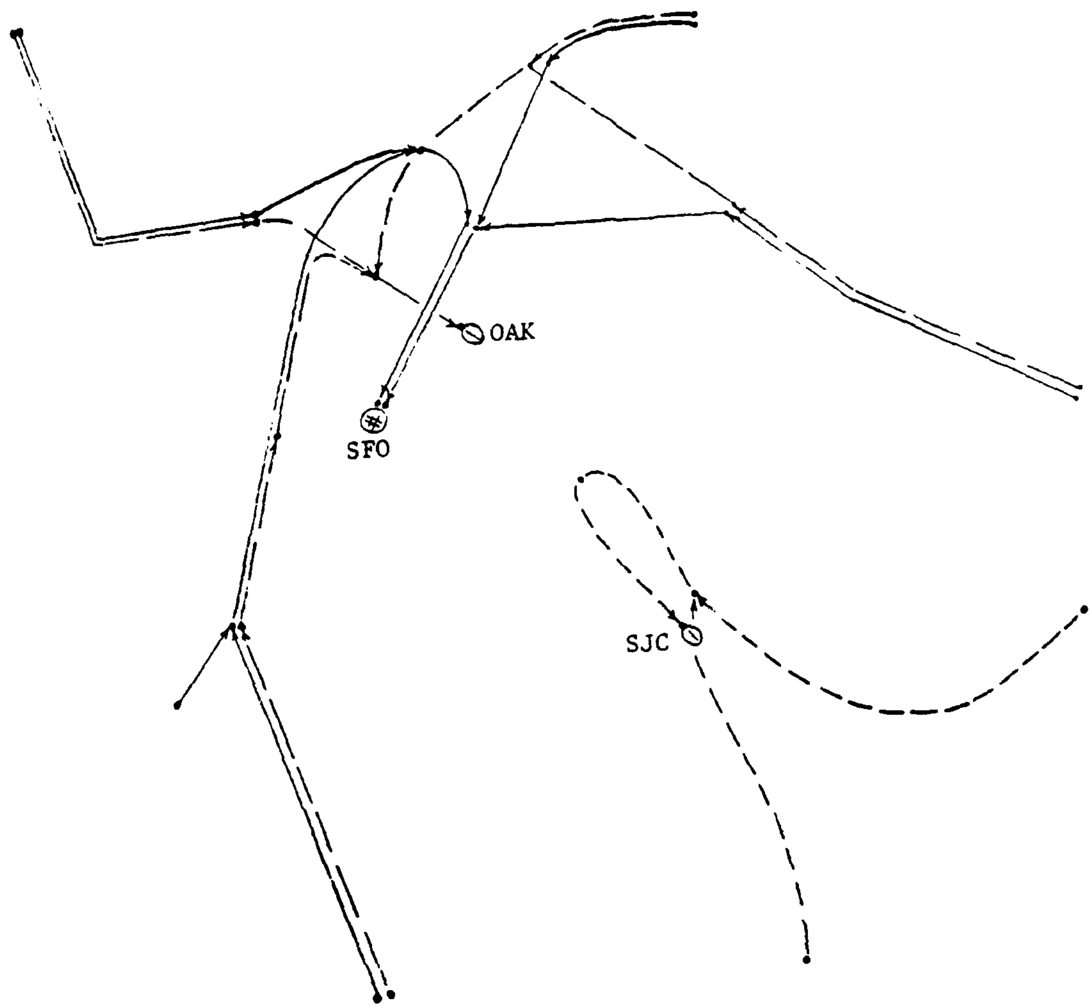

FIGURE 15. SOUTHEAST PLAN ARRIVALS

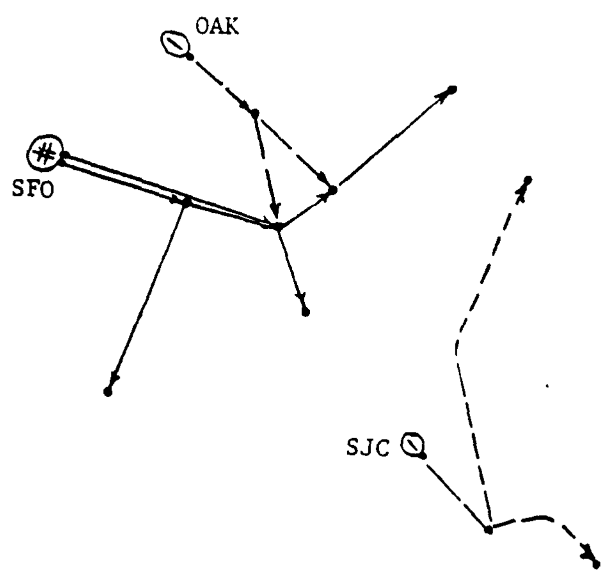

FIGURE 16. SOUTHEAST PLAN DEPARTURES

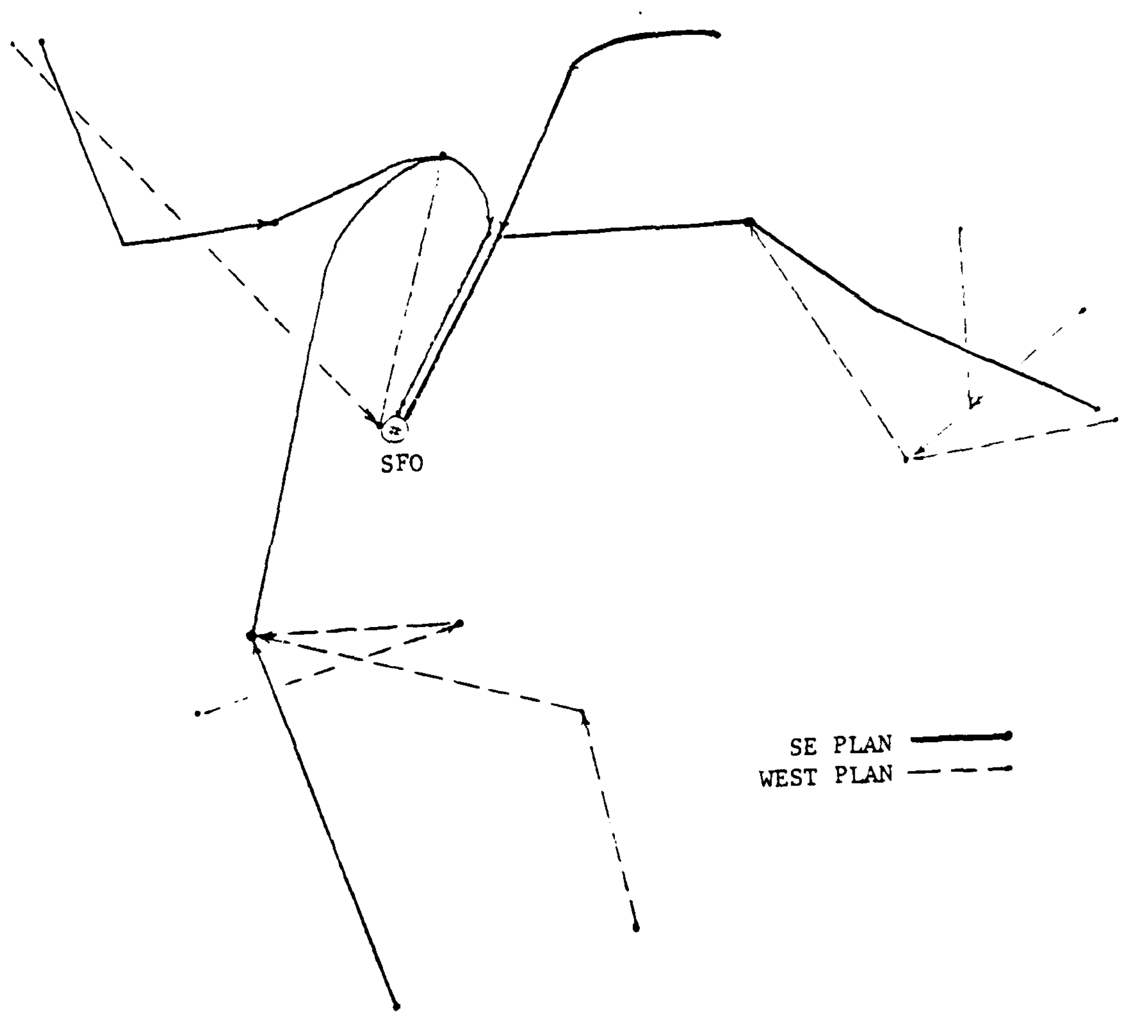

FIGURE 17. WEST PLAN TO SOUTHEAST PLAN TRANSITION

B. Results

A traffic sample was developed using flight strip data from the local ATC facilities. The sample described the routing pattern over time for 120 aircraft entering the subject system during a one-hour period under West Plan visual weather conditions. The aircraft, which were either arriving at or departing from one of the three airports, were classified according to four categories--(A) small single-engine, (B) small twin-engine, (C) large, and (D) heavy--to distinguish speed characteristics and separation requirements.

The traffic sample was loaded into AADM which developed average travel time and delay estimates for the West Plan under various VFR operating situations as shown in Table 5. The base case assumed a 3 nautical mile minimum separation at the approach fixes and 15 knot westerly wind. Additional results were obtained separately for the no wind condition, a minimum 4 nautical mile approach separation, a 10 nautical mile restriction on all SFO departures to Los Angeles, and 25 and 50 percent traffic increase assumptions. Although the travel time and delay results vary according to the assumptions, an undelayed average travel time (i.e., the difference between travel time and delay of about 10.5 minutes results in each case.

The AADM was used to simulate West Plan and Southeast Plan operation under both IFR and VFR conditions as shown in Table 6. The first two rows in Table 6 assume West Plan operations during the entire simulation period, while the next pair of rows describe Southeast Plan operations during the entire period. The last row describes the results obtained by simulating a transition from West Plan to Southeast Plan operations during the

TABLE 5

WEST PLAN SENSITIVITY

WEST PLAN VFR	AVE DELAY	AVE TRAVEL TIME
BASE CASE (3NM/15KTS)	7.46MIN	18.17MIN
NO WIND	4.67	14.90
4NM APPROACH SPACING	7.42	18.13
10NM LA ROUTE RESTRICTION	7.46	18.17
25% TRAFFIC INCREASE	13.21	23.93
50% TRAFFIC INCREASE	18.48	29.19

TABLE 6

PLAN CHANGE SENSITIVITY ANALYSIS

PLAN	AVE DELAY	AVE TRAVEL TIME
WEST PLAN VFR	7.46 MIN	18.17 MIN
WEST PLAN IFR	22.40	33.11
SE PLAN VFR	6.61	19.49
SE PLAN IFR	24.31	37.19
WEST-TO-SE PLAN VFR	9.79	22.61

simulation period. The travel time and delay statistics vary according to conditions, but the undelayed travel time for each of the all-Southeast IFR and VFR plans (i.e., 12.9 minutes) is four minutes greater than that of the corresponding West Plan operation. Similarly, the undelayed travel time associated with the VFR West-to-Southeast Plan transition is four minutes greater than the all-West Plan VFR operation.

While the actual magnitude of the data results should not be considered significant because of the experimential nature of the input specifications, the results do show the capability of AADM to evaluate alternative operating scenarios.

C. Computer Processing Costs

Table 7 provides an indication of the computer resources required by an AADM simulation run. As can be seen, the program cost only $4.10 for a single run which included extensive application of airspace traffic control Levels I, II and III, airport/airspace interface and associated input, output, and executive control logic components.

TABLE 7

COMPUTER RESOURCES

CPU TIME*	0.09	MINUTES
MEMORY*	80K	WORDS
DISK I/O*	864	ACCESSES
PRINTER*	3196	LINES
COST	$4.10	

*WEST PLAN VFR CASE WITH 120 AIRCRAFT USING SCIP IBM 370/168 UNDER DAYTIME STANDARD PRIORITY

D. Input Data

A listing of the input data file for the sample application is provided in Table 8. The input lines or card records are numbered for the purposes of reference (data were actually input by terminal keyboard entry). The first 16 cards are job control language cards and are not included in Table 8. The data shown include all information needed to exercise all of the plans considered in this demonstration; but PLAN and WIND event cards must be added between input cards 498 and 499 to define the case being considered.

The input data format is free form. Therefore, in general, the data entries do not have to be placed in specific card columns. However, there must be at least one blank space between each data entry. Also, the keywords and certain data entries must begin in column 1. In the following sections of this chapter, descriptions of the entries for each data category in Table 8 are provided, together with any restrictions on their positions on the input cards.

1. TRACE

This keyword is followed by data which specify the information to be printed in the simulation log. The word TRACE is followed by pairs of entries; the first entry is a number designating a type of information in the simulation log and the second number is set equal to one if the type of information is to be printed in the simulation log and zero if not. Any type of information not mentioned is not printed. Thus, the data on card 17 specify that information of types 1 and 2 is to be printed in the simulation log. The types of information are as shown in the following tabulation:

Type	Actions Described in Simulation Log
1	Aircraft entering the airspace
2	Aircraft exiting the airspace
3	Aircraft holding, node arrivals and node departures
4,5,6	Level I control (except paired aircraft control)
7	Level II control
8	Paired aircraft control
9	Landings and takeoffs
10	Level III control

The data on cards 18 through 109 define system nodes. Each card contains data for one node. The data entries in order of input are:

- Identification number assigned to the node (must begin in column 1).
- Altitude of the node in feet.
- Level I arrival strategy number.*
- Initial value of the in-trail strategic separation distance between aircraft in miles.
- Maximum number of aircraft that can be held at the node.
- Holding strategy number for the node.

  1--hold if there is holding at the next node in the route.
  2--hold if the holding stack at the next node is full.
  3--hold if the number of aircraft in holding at the next node plus the number approaching the node is not less than the holding stack capacity.

*See Section IV.E.1. Only Strategies 1, 2, or 3 are specified here. Strategy 4 is not fully implemented. Strategies 5 and 6 are prescribed via link data input.

Table 8

LISTING OF INPUT DATA FOR THE SAMPLE APPLICATION

```
TRACE 1 1 2 1
NODES
1         0  1  1  0  1
2         0  1  1  0  1
3         0  1  1  0  1
4         0  1  1  0  1
5         0  1  1  0  1
6         0  1  1  0  1
7         0  1  1  0  1
8         0  1  1  0  1
9         0  1  1  0  1
909       0  1  1  0  1
10        0  1  1  0  1
910       0  1  1  0  1
11       50  1  1  0  1
12       50  1  1  0  1
13     4000  1  3  0  2
14     8000  3  5  0  2
15    10000  3  5  1  2
16    10000  3  5  1  2
17     2000  1  3  0  2
18    10000  3  3  0  2
19    11000  3  5  1  2
20    11000  3  5  1  2
21     2000  1  3  0  2
22    10000  3  5  1  2
23     2000  1  3  0  2
24    10000  3  5  1  2
924   10000  3  5  1  2
25    11000  3  5  0  1
26    11000  3  5  0  1
27    11000  3  5  0  1
28    11000  3  3  1  2
29    11000  3  3  3  2
30    11000  3  5  0  1
31     4000  3  3  3  2
32    10000  3  5  0  2
33     8000  3  3  3  2
34    10000  3  5  0  2
35     6000  3  3  3  2
36     4000  3  3  1  1
37     4000  3  3  1  1
38    10000  3  5  0  1
39     7000  3  3  3  2
40    10000  3  5  0  1
41    10000  3  5  0  1
42     7000  3  3  3  2
43     7000  3  5  0  1
44     2000  3  3  3  2
45    10000  3  5  0  1
46     6000  3  3  3  2
47     3500  3  3  1  1
48     8000  3  5  0  1
49     8000  3  5  0  1
50     4000  3  5  3  1
51     2500  1  3  0  2
52     2500  1  3  0  2
53     3000  1  3  0  2
54     7000  3  3  0  2
55     8000  3  3  0  2
56     9000  3  5  1  2
57    11000  3  5  1  2
58    10000  3  5  1  2
59     3000  1  3  0  2
60     7000  3  5  1  2
61    11000  3  5  1  2
```

Table 8 (continued)

83.	62	10000	3	5	0	1
84.	63	6000	3	3	3	2
85.	64	8000	3	5	0	1
86.	65	6000	3	3	3	2
87.	66	4500	3	3	1	1
88.	67	9000	3	5	0	1
89.	68	7000	3	3	3	2
90.	69	10000	3	5	0	1
91.	70	8000	3	5	0	1
92.	71	8000	3	3	3	2
93.	72	6000	3	3	1	2
94.	73	4500	3	3	1	1
95.	74	9000	3	5	0	1
96.	75	4000	3	3	3	2
97.	76	6000	3	5	0	1
98.	77	4000	3	3	3	2
99.	78	7000	3	5	0	1
100.	79	5000	3	3	3	2
101.	80	9000	3	5	0	1
102.	81	7000	3	3	3	2
103.	82	5000	3	3	1	1
104.	83	3000	3	3	1	1
105.	983	3000	3	3	1	1
106.	84	10000	3	5	0	1
107.	85	10000	3	5	0	1
108.	86	4000	3	3	3	2
109.	87	2000	3	3	1	1
110.	LINKS					

111.	9	3	13	100	029	1	0	0	4	3	0
112.	10	4	17	50	350	1	0	0	2	3	0
113.	11	10	21	50	288	1	0	0	2	3	0
114.	12	910	21	50	288	1	0	0	2	3	0
115.	13	13	14	50	029	2	1	0	2	3	0
116.	913	21	14	90	060	2	1	0	2	3	0
117.	14	21	17	60	200	2	1	0	3	3	0
118.	15	14	15	50	029	2	1	0	2	3	0
119.	16	13	16	90	347	2	1	0	4	5	0
120.	17	17	18	130	200	2	1	0	5	5	0
121.	18	18	20	60	168	2	1	0	3	5	0
122.	19	18	19	50	135	2	1	0	2	5	0
123.	20	21	22	60	330	2	1	0	3	5	0
124.	21	12	23	30	302	1	0	0	2	3	0
125.	22	23	24	100	357	2	1	0	4	5	0
126.	23	23	924	100	121	2	1	0	4	5	0
127.	39	25	29	150	245	4	1	0	6	5	0
128.	40	26	28	100	215	4	1	0	4	5	0
129.	41	27	28	120	162	4	1	0	5	5	0
130.	42	28	29	50	215	4	1	0	2	5	0
131.	43	29	37	270	250	4	1	0	10	5	0
132.	44	30	31	360	120	4	1	0	13	5	0
133.	45	31	36	150	100	4	1	0	6	5	0
134.	46	32	33	190	060	4	1	0	7	5	0
135.	47	33	36	100	020	4	1	0	4	5	0
136.	48	34	35	150	331	4	1	0	6	5	0
137.	49	35	36	150	331	4	1	0	6	5	0
138.	50	36	1	100	281	3	0	1	4	3	51
139.	51	37	2	100	281	3	0	1	4	3	50
140.	52	38	39	150	245	4	1	0	6	5	0
141.	53	40	42	100	229	4	1	0	4	5	0
142.	54	41	42	60	162	4	1	0	3	5	0
143.	55	39	47	170	250	4	1	0	6	5	0
144.	56	42	47	230	229	4	1	0	8	5	0
145.	57	45	46	150	275	4	1	0	6	5	0
146.	58	46	47	100	275	4	1	0	4	5	0
147.	59	43	44	200	110	4	1	0	7	5	0
148.	60	44	47	250	110	4	1	0	9	5	0
149.	61	47	9	160	293	3	0	1	6	3	0
150.	62	48	50	150	333	4	1	0	6	5	0

Table 8 (continued)

151.	63	49	50	200	216	4	1	0	7	5	0
152.	64	50	11	160	302	3	0	1	6	3	0
153.	24	2	52	80	090	1	0	0	3	3	0
154.	25	1	51	80	095	1	0	0	3	3	0
155.	26	9	53	50	121	1	0	0	2	3	0
156.	27	909	53	50	120	1	0	0	2	3	0
157.	28	52	54	60	090	2	1	0	3	5	0
158.	29	51	54	60	095	2	1	0	3	5	0
159.	30	51	58	100	188	2	1	0	4	5	0
160.	31	53	54	50	145	2	1	0	2	5	0
161.	32	53	55	60	120	2	1	0	3	5	0
162.	33	54	56	50	135	2	1	0	2	5	0
163.	34	54	55	40	028	2	1	0	2	5	0
164.	35	55	57	70	028	2	1	0	3	5	0
165.	36	11	59	60	122	1	0	0	3	3	0
166.	37	59	60	60	100	2	1	0	3	5	0
167.	38	59	61	200	345	2	1	0	7	5	0
168.	66	62	63	280	280	4	1	0	10	5	0
169.	67	63	66	180	250	4	1	0	7	5	0
170.	68	64	65	110	235	4	1	0	4	5	0
171.	69	65	66	120	191	4	1	0	5	5	0
172.	70	67	68	270	110	4	1	0	10	5	0
173.	71	68	72	120	060	4	1	0	5	5	0
174.	72	69	71	280	324	4	1	0	10	5	0
175.	73	70	71	60	024	4	1	0	3	5	0
176.	74	71	72	370	010	4	1	0	13	5	0
177.	75	72	73	70	140	4	1	0	3	5	0
178.	76	73	4	140	191	3	0	1	5	3	77
179.	77	66	3	140	191	3	0	1	5	3	76
180.	78	74	75	280	280	4	1	0	10	5	0
181.	79	76	77	110	235	4	1	0	4	5	0
182.	80	75	77	150	290	4	1	0	6	5	0
183.	81	77	83	190	205	4	1	0	7	5	0
184.	82	78	79	270	110	4	1	0	10	5	0
185.	83	79	983	70	100	4	1	0	3	5	0
186.	84	80	81	280	324	4	1	0	10	5	0
187.	85	81	82	130	000	4	1	0	5	5	0
188.	86	82	983	160	025	4	1	0	6	5	0
189.	87	983	10	90	113	3	0	1	4	3	0
190.	88	83	10	90	113	3	0	1	4	3	0
191.	89	84	86	280	330	4	1	0	10	5	0
192.	90	85	86	330	255	4	1	0	12	5	0
193.	91	86	87	110	300	4	1	0	4	5	0
194.	92	87	12	130	120	3	0	1	5	3	0
195.	101	29	36	270	250	4	1	0	10	5	0
196.	102	72	66	70	140	4	1	0	3	5	0
197.	103	29	63	210	310	4	1	0	8	5	0
198.	104	31	72	190	000	4	1	0	7	5	0
199.	105	33	71	140	250	4	1	0	5	5	0
200.	106	35	71	230	270	4	1	0	8	5	0
201.	107	46	75	230	330	4	1	0	8	5	0
202.	108	39	75	210	310	4	1	0	8	5	0
203.	109	42	75	170	280	4	1	0	6	5	0
204.	110	44	79	80	285	4	1	0	9	5	0
205.	111	50	86	190	305	4	1	0	7	5	0

```
206.   ROUTES    2
207.   1  ;    3  13   14       15  ;       ;
208.   2  ;    3  13   16   ;    ;
209.   3  ;    4  17   18       20  ;       ;
210.   4  ;    4  17   18       19  ;       ;
211.   5  ;   10  21   14       15  ;       ;
212.   6  ;   10  21   22   ;    ;
213.   7  ;  910  21   17       18  20  ;       ;
214.   8  ;  910  21   17       18  19  ;       ;
215.   9  ;   12  23   24   ;    ;
216.   10 ;   12  23  924   ;    ;
217.   11 ;   25  29   37        2  ; 29 ;
218.   12 ;   26  28   29       37   2  ; 29 ;
219.   13 ;   27  28   29       37   2  ; 29 ;
220.   14 ;   30  31   36        1  ; 31 ;
```

Table 8 (continued)

```
15 ;   32  33   36        1  ; 33 ;
16 ;   34  35   36        1  ; 35 ;
17 ;   45  46   47        9  ; 46 ;
18 ;   38  39   47        9  ; 39 ;
19 ;   40  42   47        9  ; 42 ;
20 ;   41  42   47        9  ; 42 ;
21 ;   43  44   47        9  ; 44 ;
22 ;   48  50   11   ; 50 ;
23 ;   49  50   11   ; 50 ;
41 ;   25  29   36        1  ;    ;
42 ;   26  28   29       36   1    ;    ;
43 ;   27  28   29       36   1    ;    ;
51 ;    2  52   54       55       57  ;    ;
52 ;    2  52   54       55       57  ;    ;
53 ;    1  51   58   ;    ;
54 ;    1  51   54       56  ;    ;
55 ;  909  53   55       57  ;    ;
56 ;  909  53   55       57  ;    ;
57 ;    9  53   54       56  ;    ;
58 ;    9  53   54       56  ;    ;
59 ;   11  59   61   ;    ;
60 ;   11  59   60   ;    ;
61 ;   62  63   66        3  ; 25    29  63  ;    ;
62 ;   62  63   66        3  ;   26  28  29  63  ;    ;
63 ;   64  65   66        3  ;   27  28  29  63  ;    ;
64 ;   67  68   72       73       4  ; 30  31  72  ; 72 ;
65 ;   70  71   72       73       4  ; 32   33  71  ; 72 ;
66 ;   69  71   72       73       4  ; 34  35  71  ; 72 ;
67 ;   80  81   82      983      10  ;    ;
68 ;   74  75   77       83      10  ; 45  46  75  ;  38  39 75  ;    ;
69 ;   74  75   77       83      10  ; 40  42  75  ;    ;
70 ;   76  77   83       10  ;  41  42  75 77  ;    ;
71 ;   78  79  983       10  ;  43  44  79  ;    ;
72 ;   84  86   87       12  ;  48  50  86  ;    ;
73 ;   85  86   87       12  ;  49  50  86  ;    ;
84 ;   67  68   72       66       3  ;  30  31  72   ;    ;
85 ;   70  71   72       66       3  ;  32  33  71   ;    ;
86 ;   69  71   72       66       3  ;  34  35  71   ;    ;
SECTORS
1   7    9   11   13  913   15   16   20   59   24   27   28   32
         34   35
2   9   10   12   14   17   18   19   25   26   29   30   31
        33
3   9   44   46   48   70   71   72   73   74   82   84   85
       104        105        106
4   9   45   47   49   75  102
5   7   39   40   41   42   52   53   54   57   66   67   68
        78   79  103        107        108        109        110
6   9   43   69  101
7   8   23   80   81
8   8   55   56   58   60   83   86
9   8   62   63   36   37   38   89   90   91  111
10  8   21   22
11  8   50   51   76   77
12  8   61   87   88
13  8   64   92
AIRCRAFT
1 A 200 250 100 250 ; 220 250 120 250 ; 180 220 80 180 ; 3 3 4 6
2 B 200 250 120 250 ; 220 250 140 250 ; 180 220 100 180 ; 3 3 4 6
3 C 200 250 140 250 ; 220 250 160 250 ; 180 220 120 180 ; 3 3 3 5
4 D 200 250 140 250 ; 220 250 160 250 ; 180 220 120 180 ; 3 3 3 4
```

Table 8 (continued)

```
PLANS
1  1  51  51
2  2  52  52
3  3  53  53
4  4  54  54
5  5  55  55
6  6  56  56
7  7  57  57
8  8  58 . 58
9  9  59  59
10 10 60  60
11 41 61  61
12 42 62  62
13 43 63  63
14 14 64  84
15 15 65  85
16 16 66  86
17 17 67  67
18 18 68  68
19 19 69  69
20 20 70  70
21 21 71  71
22 22 72  72
23 23 73  73
AIRPORTS
1 SFO 1 2 3 4 ;
 1 1 ; ;
 2 1 ; ;
 3 ; 10 ;
 4 ; 12 ; ;
 1 2 ; ;
 2 2 ; ;
 3 ; 9 ;
 4 ; 11 ; ;
 1 ; 3 ;
 2 ; 5 ;
 3 8 ; ;
 4 8 ; ; ;
 1 ; 4 ;
 2 ; 6 ;
 3 7 ; ;
 4 7 ; ; ;
2 OAK 9 909 10 910 ;
 1 13 ; ;
 2 13 ; ;
 3 ; 17 ;
 4 ; 17 ; ;
 3 ; 18 ;
 4 ; 18 ; ;
 1 ; 14 ;
 2 ; 14 ;
 3 16 ; ;
 4 16 ; ; ;
 1 ; 15 ;
 2 ; 15 ; ;
3 SJC 11 12 ;
 1 19 ; ;
 2 19 ; ;
 3 ; 22 ;
 4 ; 22 ; ;
 1 ; 20 ;
 2 ; 20 ;
 3 21 ; ;
 4 21 ; ; ;
```

Table 8 (continued)

```
PROCEDURES
1 1 ; 40  0 40 40 40 40 0 0 2 2 2 2 ;
  2 ; 50  0 50 50 50 50 0 0 2 2 2 2 ;
  3 ; 60  0 50 55 50 55 0 0 2 2 2 2 ;
  4 ; 75  0 50 55 50 55 0 0 2 2 2 2 ;
2 1 ;  0 40 40 40 40 40 0 0 2 2 2 2 ;
  2 ;  0 50 50 50 50 50 0 0 2 2 2 2 ;
  3 ;  0 60 50 55 50 55 0 0 2 2 2 2 ;
  4 ;  0 75 50 55 50 55 0 0 2 2 2 2 ;
3 1 ; 35 40 55  0  0  0 0 0 0 0 0 0 ;
  2 ; 35 40 55  0  0  0 0 0 0 0 0 0 ;
  3 ; 35 40 50  0  0  0 0 0 0 0 0 0 ;
  4 ; 35 40 50 50  0  0 0 0 2 2 0 0 ;
4 1 ; 30 35  0 50  0  0 0 0 0 0 0 0 ;
  2 ; 30 35  0 50  0  0 0 0 0 0 0 0 ;
  3 ; 30 35  0 45  0  0 0 0 0 0 0 0 ;
  4 ; 30 35 50 45  0  0 0 0 2 2 0 0 ;
5 1 ; 35 40  0  0 55 55 0 0 0 0 0 0 ;
  2 ; 35 40  0  0 55 55 0 0 0 0 0 0 ;
  3 ; 35 40  0  0 50 50 0 0 0 0 0 0 ;
  4 ; 35 40  0  0 50 50 0 0 0 0 2 2 ;
6 1 ; 30 35  0  0 50 50 0 0 0 0 0 0 ;
  2 ; 30 35  0  0 50 50 0 0 0 0 0 0 ;
  3 ; 30 35  0  0 45 45 0 0 0 0 0 0 ;
  4 ; 30 35  0  0 45 45 0 0 0 0 2 2 ;
7 1 ; 35  0 35 35 35 35 0 0 3 3 3 3 ;
  2 ; 50  0 35 40 35 40 0 0 3 3 3 3 ;
  3 ; 65  0 30 35 30 35 0 0 3 3 3 3 ;
  4 ; 65  0 30 35 30 35 0 0 3 3 3 3 ;
8 1 ;  0 40 40 40 40 40 0 0 3 3 3 3 ;
  2 ;  0 55 40 45 40 45 0 0 3 3 3 3 ;
  3 ;  0 60 35 40 35 40 0 0 3 3 3 3 ;
  4 ;  0 75 35 40 35 40 0 0 3 3 3 3 ;
9 1 ; 40 45 70  0  0  0 0 0 0 0 0 0 ;
  2 ; 40 45 70  0  0  0 0 0 0 0 0 0 ;
  3 ; 40 45 60  0  0  0 0 0 0 0 0 0 ;
  4 ; 40 45 60 60  0  0 0 0 2 2 0 0 ;
10 1 ; 35 40  0 65  0  0 0 0 0 0 0 0 ;
   2 ; 35 40  0 65  0  0 0 0 0 0 0 0 ;
   3 ; 35 40  0 55  0  0 0 0 0 0 0 0 ;
   4 ; 35 40 55 55  0  0 0 0 2 2 0 0 ;
11 1 ; 40 45  0  0 70 70 0 0 0 0 0 0 ;
   2 ; 40 45  0  0 70 70 0 0 0 0 0 0 ;
   3 ; 40 45  0  0 60 60 0 0 0 0 0 0 ;
   4 ; 40 45  0  0 60 60 0 0 0 0 2 2 ;
12 1 ; 35 40  0  0 65 65 0 0 0 0 0 0 ;
   2 ; 35 40  0  0 65 65 0 0 0 0 0 0 ;
   3 ; 35 40  0  0 55 55 0 0 0 0 0 0 ;
   4 ; 35 40  0  0 55 55 0 0 0 0 2 2 ;
13 1 ; 55 55 55 0 3 3 ;
   2 ; 45 45 45 0 3 3 ;
   3 ; 55 55 55 0 3 3 ;
   4 ; 85 85 85 0 3 3 ;
14 1 ; 65 65 65 0 0 0 ;
   2 ; 65 65 65 0 0 0 ;
   3 ; 55 55 55 0 0 0 ;
   4 ; 55 55 55 0 2 2 ;
15 1 ; 65 65 65 0 0 0 ;
   2 ; 65 65 65 0 0 0 ;
   3 ; 55 55 55 0 0 0 ;
   4 ; 55 55 55 0 2 2 ;
16 1 ; 75 75 75 0 3 3 ;
   2 ; 75 75 75 0 3 3 ;
   3 ; 65 65 65 0 3 3 ;
   4 ; 65 65 65 0 3 3 ;
```

Table 8 (continued)

```
17 1 ; 65 65 65 0 0 0 ;
   2 ; 65 65 65 0 0 0 ;
   3 ; 55 55 55 0 0 0 ;
   4 ; 55 55 55 0 2 2 ;
18 1 ; 65 65 65 0 0 0 ;
   2 ; 65 65 65 0 0 0 ;
   3 ; 55 55 55 0 0 0 ;
   4 ; 55 55 55 0 2 2 ;
19 1 ; 45 45 0 3 ;
   2 ; 45 45 0 3 ;
   3 ; 60 60 0 3 ;
   4 ; 70 70 0 3 ;
20 1 ; 60 60 0 0 ;
   2 ; 60 60 0 0 ;
   3 ; 50 50 0 0 ;
   4 ; 50 50 0 2 ;
21 1 ; 40 40 0 3 ;
   2 ; 65 65 0 3 ;
   3 ; 55 55 0 3 ;
   4 ; 65 65 0 3 ;
22 1 ; 60 60 0 0 ;
   2 ; 60 60 0 0 ;
   3 ; 55 50 0 0 ;
   4 ; 50 50 0 2 ;
METERING
37 1
 25 11 ;
 26 12 ;
 27 13 ;
36 1
 30 14 ;
 32 15 ;
 34 16 ;
47 1
 45 17 ;
 38 18 ;
 40 19 ;
 41 20 ;
 43 21 ;
66 1
 62 61 62 ;
 64 63 ;
73 1
 67 64 ;
 70 65 ;
 69 66 ;
983 1
 80 67 ;
 78 71 ;
83 1
 74 68 69  ;
 76 70 ;
FLOWS  0.1
2 120
 25 250 5 0 5 25 11 ;
 26 250 5 0 5 25 12 ;
 27 250 5 0 5 25 13 ;
1 120
 30 250 5 0 5 25 14 ;
 32 250 5 0 5 25 15 ;
 34 250 5 0 5 25 16 ;
```

Table 8 (concluded)

```
472.   9 120
473.    45 250 5 0 5 25 17 ;
474.    38 250 5 0 5 25 18 ;
475.    40 250 5 0 5 25 19 ;
476.    41 250 5 0 5 25 20 ;
477.    43 250 5 0 5 25 21 ;
478.   11 120
479.    48 250 5 0 5 25 22 ;
480.    49 250 5 0 5 25 23 ;
481.   3 120
482.    62 250 5 0 5 25 61 62 ;
483.    64 250 5 0 5 25 63 ;
484.   4 120
485.    67 250 5 0 5 25 64 ;
486.    70 250 5 0 5 25 65 ;
487.    69 250 5 0 5 25 66 ;
488.   10 120
489.    80 250 5 0 5 25 67 ;
490.    78 250 5 0 5 25 71 ;
491.    74 250 5 0 5 25 68 69 ;
492.    76 250 5 0 5 25 70 ;
493.   12 120
494.    84 250 5 0 5 25 72 ;
495.    85 250 5 0 5 25 73 ;
497.   TIMING 2.0  0.0  .1  .1
498.   GO
499.   MULTDEP   .0   1   3   12   1   *
500.   MULTDEP   .0   1   4    5   1   *
501.   MULTDEP   .0   2   3    9   1   *
502.   MULTDEP   .0   3   1    1   1   *
503.   MULTDEP   .0   3   2    2   1   *
504.   MULTDEP   .0   3   3    3   1   *
505.   MULTDEP   .0   4   3    8   1   *
506.   MULTDEP   .0   5   1    1   1   *
507.   MULTDEP   .0   5   2    1   1   *
508.   MULTDEP   .0   5   3    2   1   *
509.   MULTDEP   .0   6   3    1   1   *
510.   MULTDEP   .0   7   3    1   1   *
511.   MULTDEP   .0   8   3    1   1   *
512.   MULTDEP   .0   9   3    2   1   *
513.   MULTDEP   .0  10   3    2   1   *
514.   MULTARR   .0  11   3    9   1   1   *
515.   MULTARR   .0  11   4   11   1   1   *
516.   MULTARR   .0  12   2    2   1   1   *
517.   MULTARR   .0  12   3    1   1   1   *
518.   MULTARR   .0  13   3    3   1   1   *
519.   MULTARR   .0  14   2    1   1   1   *
520.   MULTARR   .0  14   3    7   1   1   *
521.   MULTARR   .0  15   4    1   1   1   *
522.   MULTARR   .0  16   3   14   1   1   *
523.   MULTARR   .0  17   3    5   1   1   *
524.   MULTARR   .0  18   3    2   1   1   *
525.   MULTARR   .0  19   3    2   1   1   *
526.   MULTARR   .0  20   1    1   1   1   *
527.   MULTARR   .0  20   2    2   1   1   *
528.   MULTARR   .0  21   1    1   1   1   *
529.   MULTARR   .0  21   2    1   1   1   *
530.   MULTARR   .0  22   3    3   1   1   *
531.   MULTARR   .0  23   3    3   1   1   *
```

3. LINKS

The data on cards 110 through 205 define the links. Each card contains data for one link. The data entries in order are:

- Identification number assigned to the link (must begin in column 1)
- Number of the initial node of the link.
- Number of the terminal node of the link.
- Length of the link in tens of miles.
- Average heading of the link in degrees.
- Type number of the link.
- Overtake flag

  1--no overtaking allowed.
  0—overtaking allowed.
- Waketurbulence flag

  1—try to avoid having light aircraft trailing heavy aircraft.
  0—no light/heavy aircraft sequencing necessary.
- Maximum number of aircraft allowed on the link.
- Maximum delay in minutes that can be absorbed by vectoring an aircraft on the link.
- Number of the mate link.

4. ROUTES

The data on cards 206 through 258 define system routes. Each card contains data for one route. The data entries in order are:

- Identification number assigned to the route (must begin in column 1)
- Route departure separation distance restriction (in miles), if any (the default value for this parameter is entered immediately after the keyword "ROUTES").
- ";"
- List of node numbers defining the primary route, terminated by a ";".
- Lists of nodes defining "transition" routes terminating on the primary route, each list terminated by a ";".
- A node, if any, on the primary route beyond which aircraft on the route are not to be rerouted in the event of a plan change.
- ";".

AD-A090 781 SRI INTERNATIONAL MENLO PARK CA F/G 1/2
AIRPORT AND AIRSPACE DELAY MODEL DESCRIPTION.(U)
OCT 79 J C BOBICK, G J COULURIS DOT-FA77WA-4033
UNCLASSIFIED FAA-AVP-79-11 NL

2 OF 2
AD A
090781

END
DATE
FILMED
11-80
DTIC

The data for a single route may be placed on more than one card. However, column 1 on all cards except the first must be left blank. This rule holds in general for the input.

5. SECTORS

The data on cards 259 through 276 define the airspace sectors. Data for each sector must begin in column 1; data on successive cards for the same sector must not be placed in column 1. The data entries for each sector in order of entry are:

- Identification number assigned to the sector (must begin in column 1).
- Maximum number of aircraft allowed in the sector because of controller workload constraints.
- List of links in the sector.

6. AIRCRAFT

The data on cards 277 through 281 define speed and minimum separation requirements for aircraft of various types. Each card contains data for one aircraft type. The data entries in order are:

- Aircraft type number
- Aircraft type name
- Nominal speed in knots of this type of aircraft on each of the types of links.
- ";"
- Maximum speed in knots of this type of aircraft on each of the types of links.
- ";"
- Minimum speed in knots of this type of aircraft on each of the types of links.
- ";"
- Minimum allowable separation distance in miles for this type of aircraft trailing each of the other types of aircraft.

In cases where many types of links and aircraft are defined, more than one card may be required to input data for a single aircraft type. In this case, column 1 of cards other than the first must be blank.

7. PLANS

The data on cards 282 through 305 define the route transitions among the various plans. Each card contains data for one route. The data in order of input are:

- A specific route number.
- Number of the route onto which traffic transitions from the specified route when changing to plan 2.
- Repeat above entry for plan 3, 4, etc.

8. AIRPORTS

Cards 306 through 345 contain the data defining the airports and specifying the arrival and departure procedures to be used in each of the airport plans. Data on cards 307-323 contain data for the first airport, namely, San Francisco International. The data entries for this first airport are:

- Number assigned to the airport (must begin in column 1).
- Name assigned to the airport.
- List of numbers of the airport/airspace interface nodes associated with this airport, terminated by a ";".
- Plan number, followed by a list of arrival procedures to be used for aircraft arriving at the first associated airport/airspace interface node under this plan, followed by a ";", then a list of departure procedures to be used for aircraft departing through the first airport/airspace interface node under this plan, followed by a ";".
- Repeat the above step for each plan for the first airport/airspace interface node, then enter a ";" after all entries for the first node.
- Repeat the preceding two steps for the second, third, etc. airport/airspace interface nodes.

The only entry in card column 1 is the first data entry for each airport. The above data must be provided for each airport in the modeled system. Oakland airport data are contained on cards 324 through 336; San Jose airport data are contained on cards 337-345.

9. PROCEDURES

Cards 346 through 434 contain data specifying the runway occupancy and airspace separation constraints among procedures. Data on cards 347 through 350 define the constraints that aircraft performing procedure 1 have on subsequent related procedures. In this case, procedures 1 through 6 are related. The data entries for each procedure are:

- Number of the procedure (must begin in column 1).
- Aircraft type number, followed by a ";".
- Time periods (e.g., runway occupancy times) in seconds during which related procedure may not be executed after the given procedure is executed by the designated type of aircraft.
- Minimum airspace distances from an airport, beyond which an aircraft of the specified type executing the given procedure must be for there to be no conflict with each related procedure.
- ";".
- Repeat all but the first entry for each of the other aircraft types. No data entry, except the first for each procedure should appear in column 1.

METERING

The data on cards 435 through 462 specify where Level II control actions are to be applicable. The data consist of specifying "POST" nodes and the associated "METER" nodes. The data for the first POST/METER systems are contained on cards 436-439. The data entries in order are:

- Number of the POST node (must begin in column 1)
- Level II strategy to be used (only strategy 1 is implemented).

- Number of the associated METER node, followed by a list of route numbers on which traffic passing through this node is subject to Level II control actions, followed by a ";".
- Repeat above entry for each associated METER node.

11. FLOWS

The data on cards 463 through 495 specify where Level III control actions are to be taken. The data entry on card 463 after the "FLOWS" keyword is the time interval in hours between Level III updates. The remaining data consists of specifying "FLOWPOST" nodes and associated "FLOWMETER" nodes. Data for the first FLOWPOST/FLOWMETER system are contained on cards 464 through 467. The data entries are:

- Node number of the FLOWPOST node (must begin in column 1).
- Average speed in knots for traffic passing through the FLOWPOST node.
- Node number of the first associated FLOWMETER node.
- Average speed in knots for traffic passing through this FLOWMETER node.
- Distance increment in miles for in-trail separation settings.
- Round-off flag
  - --1 if distance settings are to be rounded to the nearest lower increment
  - --0 if distance settings are to be rounded to the nearest increment.
- Minimum in-trail separation distance setting for this FLOWMETER node.
- Maximum in-trail separation distance setting for this FLOWMETER node.
- List of routes passing through this FLOWMETER node for which Level III control is applicable, followed by a ";".
- Repeat all data entries, except the first two, for each associated FLOWMETER node.

12. TIMING

The data entries contained on card 497 are:

o Time in hours when the simulation is to be terminated.

- Time in hours at which the seed period ends.
- Time in hours when the first periodic simulation report is to be printed.
- Time in hours between periodic simulation reports.

13. MULTDEP

The data on cards 499 through 513 specify external events for generating aircraft departure requests. The entries on each of these event cards are:

- MULTDEP (must begin in column 1).
- Time in hours when the event is to occur.
- Route number.
- Aircraft type number.
- Number of aircraft requesting departure.
- Time interval in hours over which the departure requests are to be randomly distributed (using a uniform distribution); the departure requests being for the aircraft type and route given.
- "*".

14. MULTARR

The data on cards 514 through 531 specify external events for generating aircraft arrivals into the modeled airports. The entries for each of these events are analogous to those for the MULTDEP event. The only difference is that an additional entry is required immediately before the "*" entry. This entry defines the probability distribution of arrival times; a one is entered for the uniform distribution.

E. Setting the Airport Plan and Wind Conditions

As mentioned earlier, the above data include the data required to exercise all four airport plans: the only additions needed to define the case are PLAN and WIND event cards between cards 498 and 499.

Entries contained on a PLAN event card are:

- PLAN (beginning in column 1).
- Time in hours when this plan change event is to occur.
- New plan number.
- Time period in hours after this plan change before departure can resume.
- Arrival clear flag

  1—if departures under the new plan are to be held until all pending arrivals which cannot transition to the new airport plan have landed.

  0--if the above constraint is not applicable.
- "*".

Entries contained on a WIND event card are:

- WIND (beginning in column 1).
- Time in hours when this WIND event is to occur.
- Windset number where the wind conditions are to be set.
- Direction from which the wind is coming in degrees.
- Speed of the wind in knots.
- "*".

The cards that need to be inserted between cards 498 and 499 for the various cases are tabulated below (all links are in windset 1 by default):

<u>WEST PLAN VFR</u>

WIND	0.0	1	270	15	*

<u>WEST PLAN IFR</u>

WIND	0.0	1	270	15	*
PLAN	0.0	2	0.0	0	*

<u>SE PLAN VFR</u>

WIND	0.0	1	180	15	*
PLAN	0.0	3	0.0	0	*

SE PLAN IFR

WIND	0.0	1	180	15	*
PLAN	0.0	4	0.0	0	*

WEST-TO-SE PLAN VFR

WIND	0.0	1	270	15	*
WIND	.25	1	180	15	*
PLAN	.25	3	0.0	1	*